RANGE MANAGEMENT

PRINCIPLES and PRACTICES

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TO HELEN

PREFACE

This book has been a long time in the making. A preliminary version of it has been used in my classes in agriculture, botany, forestry, geography, and other sciences. During these "apprenticeship" years, each chapter has undergone several revisions in organization and subject material, as prompted by experience and by changing emphasis in range research and practical management.

The book is in no way a revision or condensation of my earlier ones: *Range and Pasture Management*, published in 1923; *Native American Forage Plants*, 1924; and *Livestock Husbandry on Range and Pasture*, 1928, works that have largely "had their day."

The states west of the 100th meridian have always been and will continue to be primarily dependent on the range for their agricultural wealth. Proper use and conservation (but not nonuse) of the range resource is a basic necessity to the West and the nation, a fact that unfortunately is realized by far too few.

The West is not receiving maximum returns from the range-livestock industry. The past century has witnessed severe competition for feed, with complete disregard for the welfare of the cover and the soil, the lands having been left in a severely punished condition; but many leaders have awakened to the responsibility of putting this resource in order. This interest is further indicated by the organization in 1947 of the American Society of Range Management. Its membership, already in excess of 2000, is essentially professional range managers and enterprising stockmen. It has been my privilege and deep satisfaction since 1907 to contribute in a small way to the range-research program and to observe how research knowledge is being made the vital foundation of improved range-management practices. To continue this vital advancement we must have a progressively better trained research personnel. To this end I have earnestly endeavored to incorporate in this volume all the more important range-research advancements.

This book—more than others before—aims to balance considerations on the care and management of range lands and its grazing animals with the sciences upon which sound practices must be based. For this reason the work should be as useful to stockmen and public range administrators as to students of technical range management. This

balance of subject matter led to the title *Range Management, Principles and Practices*

The aim has been to treat the text material comprehensively enough to serve, where so desired, as a complete work for a course in range management But collateral readings of selected current Federal and state publications are recommended to broaden the student's knowledge of the field as a whole Some of the more pertinent references presented in the bibliography at the end of each chapter may be used as a guide to additional background readings

For convenience in organization, the subject matter is presented under four subdivisions

Part 1, "Range Management in Perspective," defines range management, compares this subject with related fields, and evaluates the end products of the range, it reviews world grazing practices and problems, it discusses the application of physiology and ecology to range problems, and it considers the physical and vegetal characteristics of United States grazing lands as well as their historical development as grazing commons

Part 2, "Native Range Forage Plants," points out why the livestock food plants are basic to range livestock production, and it illustrates, describes, and discusses a large number of the more important native western range forage grasses, grasslike plants, forbs, and browse vegetation Whereas the forage species discussed are those of special importance for students of all areas, the range instructor would be expected to include the more economically useful plants of his particular region

Part 3, "Improvement and Management of Range and Stock," considers artificial and natural reseeding, control of noxious woody vegetation, and those management practices that are common to all range livestock, such as their water requirements, water development, supplemental range feeding and range sanitation This is followed by specific discussion of the husbandry and management of cattle, sheep, and goats on the range, including cattle grazing in the southeastern states Due consideration is given to range condition, forage utilization, and range surveys as well as to the economic, physical, and social aspects of ranching

Part 4 *Protection of Range Resources and Range Livestock,"* points out ways of avoiding serious damage by livestock to timber reproduction, it recommends the use of shade trees and shelterbelts for the comfort and protection of livestock, it describes and pictures in color plates the more troublesome poisonous range plants, and it tells how to prevent livestock losses Due consideration is also given

to the foraging and predatory wildlife of the range, soil erosion and its control, and to the administration of grazing on public lands, including highlights of the grazing administration controversy between a few articulate stockmen and the United States Forest Service.

I wish to express my indebtedness to my colleagues who have read critically one or more chapters that deal with topics of their special fields. Thanks are especially due to Messrs. Hudson G. Reynolds and Ned A. Smith for their constructive reading of several chapters. Without this cooperation the work could not have served its fullest purpose.

It is also a pleasure to acknowledge the courtesies of individuals who through their organizations or personal collections have contributed illustrations. Photographs not taken by myself have been properly credited in the text. With few exceptions the line drawings are the work of Miss Aida B. Montier, whose cooperation is likewise much appreciated.

It is probably unavoidable that some errors have occurred in the bibliographic references or numerical facts presented. I would greatly appreciate having such oversights called to my attention so that they may be corrected as expeditiously as possible.

ARTHUR W. SAMPSON

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PART 1

RANGE MANAGEMENT IN PERSPECTIVE

Chapter 1

CONCEPTS ON RANGE MANAGEMENT AND ON PRODUCTS OF THE RANGE

Sound range management plays an important part in insuring the never ending chain of human needs The soil is the basic resource, producing forage that is converted by animals into products for human consumption About one-third of all expenditures for food and clothing is for animal products—meat and milk, fats, leather, and wool (*12*) [1]

The main links of this chain of human needs are soil development and maintenance, continuous production of desirable forage, and grazing by domestic animals and wildlife The chain is disrupted when the topsoil is eroded away, as by unwise grazing practices

Livestock production dates from primitive times Grazing animals, in the beginning, subsisted entirely upon the native vegetation, supplying man with food, clothing, and power, later they provided other commodities of exchange for needed articles As population increased, more animals were produced In many localities they became so numerous as to jeopardize forage growth and other uses of the land It soon became evident that careful husbandry of pasture lands was imperative if continuous economic livestock production was to be enjoyed

Although soil conservation and improved pasture management are gaining in popularity, grazing practices are too often at a primitive level, especially in the extensive nomadic grazing areas of the Old World (*4*) Since nomadic grazing is associated with isolation, lack of formal markets, sparse vegetation, limitless free range, inferior animals, inadequate water, and almost continuous moving of the stock, management of the forage crop receives no consideration (*8*) Modern commercial grazing, on the other hand, is associated with investment in land, improvement at ranch or farm headquarters, scientific breeding of livestock, sustained yield grazing, and maximum production of quality animals These competitive conditions demand application of approved grazing practices

[1] Italic numbers in parentheses refer to literature cited at end of chapter

Range-Land Concepts

The following discourse defines, describes, and delimits the field that the subject of efficient production and consumption of range forage encompasses. It also covers the conversion of forage into the end commodities of meat and other animal products.

Range, Pasture, Pasturage, Range Management, and Grazing Management Defined

For clear understanding of later considerations it is essential at the outset to define and delimit certain terms.

Range. This refers to large, naturally vegetated, mostly unfenced lands of low-rainfall areas that are grazed by domestic livestock and game mammals. In the United States the range lands occupy the greater part of the western half of the continent, and the 17 states included therein are spoken of as "the western range states." Approximately 30 percent of the grazing capacity in 11 of these states is on land in public ownership. The western range region is generally too dry, rough, elevated, or otherwise unsuitable for farming.

Some natural grazing areas in the southeastern states are likewise referred to as range. On all these wild lands livestock and game animals consume practically all the palatable vegetation that is accessible. Few of these lands grow domesticated or otherwise improved forage crops, and soil fertilization is seldom attempted.

Pasture. The improved, irrigated grazing lands in the West and those in the Midwest and East that receive abundant rainfall and that are generally fertilized and seeded to domesticated forage plants are ordinarily fenced. These areas are called pastures to distinguish them from open, natural range lands. "Pasture," though more strictly referring to small, fenced grazing grounds, applies to all areas upon which livestock are grazed. In this book "range" and "pasture" are used synonymously.

Pasturage. This is a collective term synonymous with "forage." It includes all vegetation—grasses and grasslike plants, forbs,[2] and the fruits and twigs of trees and shrubs—upon which grazing animals subsist. Palatable woody vegetation is called "browse," and feed consisting of berries, acorns, and other nuts that fall to the ground is termed "mast." The term "herbage," as used in range management, includes all vegetation without reference to its palatability.

Range Management. The term "range (or pasture) management" is sometimes so narrowly defined as merely to imply conservative

[2] Forbs are nongrasslike (broad leaved) herbs, sometimes called weeds.

forage use of the range with little thought, perhaps, of the yearlong needs of the animals or of the pressure imposed on areas that are used to supplement the natural range units at critical intervals. Also, the husbandry of the range as a whole is too frequently overlooked, and this defeats the implied meaning of "range management." As defined below, the term is broad ennugh to include all phases of pasture utilization and maintenance:

Range management is the science and the art of procuring maximum sustained use of the forage crop without jeopardy to other resources or uses of the land.

This definition presupposes thorough familiarity with the resources and condition of the grazing area and indicates that no single technique will necessarily be equally effective in all climatic regions. The reference to sustained (forage) yield implies, among other things, needed adjustments in the grazing use of individual range units and the adoption of conservative grazing practices at all times. Reference to "other resources or uses" calls attention to due consideration of watersheds, timber, soil, streams, game animals, and recreation sites.

Range management, like ecology, covers a broad field; hence its effective application leans on many sciences. These interrelations may be likened to a wheel where range management is the hub (Fig. 1). From this point radiate six "spokes" or key divisions. (1) The raw materials lead directly to soils on the felly of the wheel where precipitation, temperature, water, and nutrients are the primary factors and where microbiology, irrigation, soil fertility, plant nutrition, physiology, taxonomy, genetics, and range ecology form a segment of the rim. (2) Integrating organisms, which lead directly to plants, are dependent upon water and nutrients and provide nourishment and shelter for the animals. Here belong forage and noxious plants, agronomy, and the nutrition and physiology of animals. (3) The market products are derived from both domestic and wild animal life as dealt with in vertebrate zoology, veterinary science, and the study of breeds and breeding. (4) The land manager involves man and his animals, as well as predator and rodent control, management of big game, range administration, and grazing in relation to the welfare of the forest and other land resources. (5) Conservative and best uses of the range lead to land economics, conservation of the soil, and various special economic range problems, including finance. (6) Environmental influences concern a complex that leads directly to a consideration of climate, erosion control, proper land use, and a consideration of land values and settlemenr. This field is chiefly concerned with such

disciplines as meteorology, geology, and mineralogy, and the morphology, physics, and chemistry of soils.

If the range-management "wheel" makes clear to the reader that many interwoven subjects enter into the solution of range problems, it will have accomplished its primary aim.

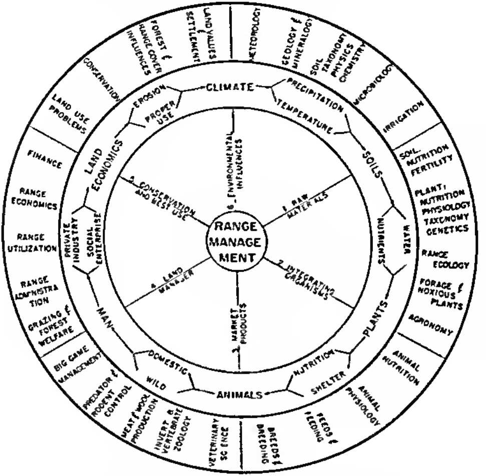

FIG. 1. A schematic "wheel" design of range (pasture) management and its integrating organisms and disciplines The range manager, like the ecologist, leans on many fields of basic and applied science as background material in drawing plans for rational grazing-land use.

Grazing Management. This term refers to the care and handling of livestock on the range, whereas range management deals more specifically with the welfare of the forage crop and the soil. The topic of grazing management is primarily concerned with selection of stock that will best utilize the forage of a given range area and with such phases of handling the animals as their proper distribution over the

range and their protection from injury or death losses. A rational, well-executed grazing-management plan is essential to good range management and brings the biggest economic returns.

Fields Allied to Range Management

Closely related to range management are such subjects as agronomy and animal husbandry. They, too, are dependent upon knowledge of the many basic sciences. By definition, agronomy and animal husbandry overlap little, if at all, the field of range management. Agronomy is essentially concerned with the production of grains, fodders, and various supplemental livestock feeds and with domesticated grass crops grown chiefly on cultivated fields and meadows. Animal husbandry is essentially concerned with the breeding, care, and production of domestic livestock. A knowledge of agronomy and animal husbandry, however, is highly useful to the range manager, though these subjects apply less directly to the understanding and solution of range problems than subjects such as plant physiology, ecology, and taxonomic botany.

Forestry and Range Management

Because domestic livestock are grazed over vast forest areas as an integral part of multiple use of these lands, forestry and range management have come to be intimately associated. This fact has induced many colleges and universities of the West to organize instruction in range management and pasture researches in the forestry department. Both forestry and range management are built around the philosophy of long-time land-use planning.

Field interrelations of range and forest production are particularly apparent in five major branches of forestry: silviculture, forest protection, forest management, forest economics, and forest influences.

Silviculture is concerned with the reproduction and growth of successive timber crops. The aim is to prescribe cutting practices that will provide seed crops or coppice sprouts for future timber stands. Tree reproduction may be favored by grazing off the forage cover that might otherwise compete severely with tree seedlings. But excessive livestock browsing may be harmful to silvicultural practices where desirable, palatable seedlings and/or sprouts are destroyed. By working together, the range conservationist and the silviculturist can decide on the most satisfactory season and intensity of grazing least destructive to the forest and the pasturage.

Forest protection deals with the detection, prevention, control, and suppression of agencies injurious or destructive to the forest. It con-

siders the control of insects, diseases, and fire on the forest, fire being the one most influenced by grazing practices. Grazing off inflammable vegetation is useful in checking the spread of fire and decreasing its intensity. However, in order not to injure timber reproduction, grazing must be conservative and done when the herbage is succulent.

Forest management is chiefly concerned with computation of income from forest areas, establishment of cutting cycles, and formulation and conduct of long range plans of operation. Invading vegetation after logging is often important to the forest manager, since the forage may return enough revenue to pay the taxes and other carrying charges until the timber reproduction predominates. Obviously, the grazing practice adopted must be coordinated with growth requirements of the forest.

Forest economics has to do with the needs, values, and policies of forest lands *in relation to the public*. The forest economist must decide whether temporary grazing returns are justified on a logged-off unit. What is gained in fire control by grazing the area? Is the community dependent upon the grazing resources of the forest? What effect has grazing on the other resources of the areas? To answer such questions the forest economist must work closely with the range manager.

The subject of *forest influences* treats of watersheds and their management and involves such questions as maximum, continuous yields of usable water. Again, grazing may be a tool to minimize fire hazard. Probably no field of forestry is as closely allied to range management as forest influences on areas where both forage and timber crops are utilized.

End Products of Range Forage

Livestock probably consume no less than three fourths of the products of the improved lands and practically all accessible feed on the natural range, but these raw materials have little value until they are converted into usable products for human consumption.

The "end products" of the range constitute a wide variety of producer and consumer goods that come from the range animals. For convenience in discussion these are divided into inedible and edible products.

Inedible Products

The principal inedible products obtained largely from range animals include hides, skins, wool, oleo oil, and mohair.

Hides, kips (from calves and very young cattle), and the better skins (from sheep and goats) (*5*), are high priced items when considered on a per pound basis. Indeed, the tanner sometimes pays as much or

more for superior flayed and cured cattle hides and kips than the butcher pays for the dressed carcasses of these animals (*16*, *19*). In cattle about 7 percent of the live weight and about 11 percent of the value of the animal lie in the hide. In calves the skin is worth about 20 percent of the value on the hoof. Although the United States produces more leather than any other nation (*13*), many hides and skins must be imported.

The importance of wool and mohair lies in the fact that they are the only animal fibers produced commercially in North America for spinning. In 1939, when price and production were probably close to those of average years, the United States produced 361,689,000 pounds of shorn wool and 64,500,000 pounds of pulled wool (which is obtained from skins of slaughtered sheep). These figures represent an average clip of 8 pounds from the 45,195,000 animals shorn (*17*). Shorn wool commanded an average local market price of 22.3 cents per pound and a gross cash income of $80,683,000. The cash annual income from sheep, lambs, and mutton[3] was $172,497,000 (*18*). This divides at an approximate ratio of 1:2.1 in gross income between wool on the one hand and mutton and lamb on the other. In 1939 (*15*) the 4,068,000 goats yielded 18,785,000 pounds of mohair—an average of 4.6 pounds per animal—which commanded an average local market price of 47.3 cents per pound and a total cash income of about $9,000,000. So great is the demand for wool and mohair that the textile mills of the United States have had to import about 40 percent of their requirements.

An important by-product of wool is oleo oil, a purified wool fat or "grease" that enjoys extensive domestic and industrial uses.

Mohair is used mainly in the manufacture of plush fabrics for automobiles and furniture and to a lesser extent for clothing.

Other inedible articles, classed as strictly by-products, are the glands, notably thyroid, parathyroid, pineal, pituitary, thymus, adrenal, gonads, and pancreas. From these are derived such pharmaceuticals as insulin, pancreatin, thyroid extract, and adrenalin. Included in the inedible by-products are the bones, blood, hoofs, horns, and intestines, which are processed for such articles as feeds, fertilizers, gelatin, and glue (*16*).

Edible Products

In most stock-raising countries of the world the chief agricultural pursuit is that of producing good quality of beef, veal, mutton, and lamb (*10*). This should be accomplished through sustained forage production.

[3] Does not include value of sheep and lambs slaughtered for home consumption, which in 1939 totaled $2,145,000.

In the United States the production of cattle and calves in 1940 was estimated at 15.7 billion pounds and the average price per hundred for cattle was $7.56 and for calves $8.83 (*15*).

The estimated production of sheep and lambs in 1940 was 2.0 billion pounds and the average price per 100 pounds was $3.95 and $8.10 respectively (*15*).

In addition to the primary dressed meat, the edible products also include such meat by-products as brains, kidneys, liver, meat portions of the head, sweetbreads, tails, tongues, tripe, and intestines used for sausage casings.

Imports and Exports of Meat

The world-wide demand for meat focuses interest on the business of its proper distribution. How large is the importing and exporting meat trade? Which are the leading importing and exporting countries? How stable is this field of commerce? How about its future expansion? These and similar points concern the consumer, the producer, the economist, students of range management, and others.

With refrigeration and improved methods of processing, including canning and dehydration, meat can now be shipped anywhere. These advances have greatly influenced the quality and breeding of stock in some countries.

The world's exports and imports on beef and veal, mutton and lamb, and pork are summarized in tons of meats in Fig. 2. The 8 main exporting countries are listed on the right in decreasing order of their importance in this industry, and 7 main importing countries are listed on the left in increasing order of their meat imports (7, *10*).

Argentina leads the world in meat exports, New Zealand is second, followed by Denmark, Australia, Uruguay, the United States, Canada, and Brazil, in the order named. Argentina is also first in the export of beef, Australia being second, Uruguay third, New Zealand fourth, and Brazil fifth. In mutton and lamb, New Zealand is by far the heaviest exporter and is followed by Australia and Argentina. In pork exports, Denmark far exceeds other nations, the United States being second, followed by Canada, Argentina, and New Zealand.

Whereas most of the importing countries produce great quantities of meat themselves, their large populations require additional imports. Great Britain leads in all kinds of meat imports even though she produces large numbers of meat animals for home consumption. Italy, France, and Germany, *in the order named*, are the next largest meat-importing nations. They are followed by the United States, Japan, and Russia. The Scandinavian and some other European countries are

practically self-sufficient in their meat requirements, as are also most of the South American republics. The world trade in meat with the Asiatic and African countries is of relatively little importance.

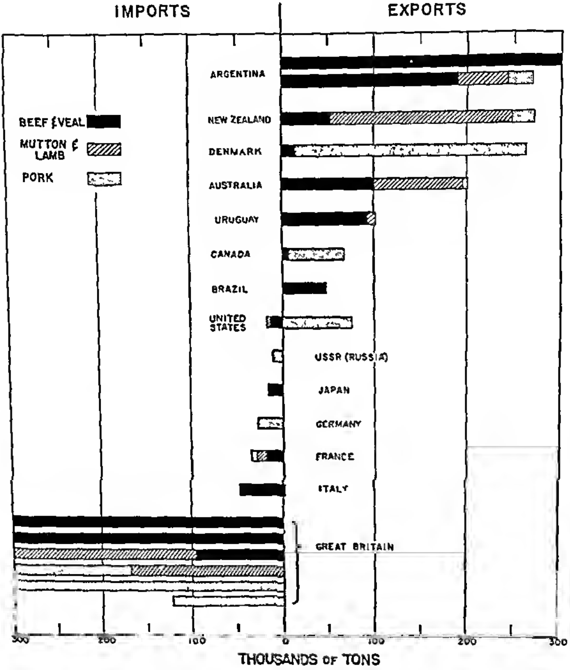

FIG. 2. Comparative exports and imports of meats by leading meat-eating nations.

Although meat is a prominent exchange commodity among many nations, mismanagement of the meat trade has sometimes led to grave political situations, as, for example, between Argentina and the United States (*3*, *14*).

Per Capita Meat Consumption

The amount and kind of meat consumed by the different nations vary with taste, custom, and habit, with geographic location, religion, season of the year, and the purchasing power of the consumer (*6*)

Four countries—Uruguay, Argentina, New Zealand, and Australia—clearly lead all others in the annual per capita consumption of meat. In Great Britain, the United States, and Canada the annual per capita consumption is approximately the same—about 139 pounds. Germany, Belgium, Italy, and Russia follow in the order listed. In the Orient (*11*) per capita meat consumption is but a fraction of that eaten even in Russia.

The reason that meat plays such an important part in the diet of the leading nations apparently lies in its high value as food.

Meat as Food

Meat is a natural food. Primitive man, like the human of today, turned to animals for his food requirements. Long before he tilled and improved crop plants man became a skilled hunter, killing animals for his subsistence.

Meat substitutes have never been popular because they lack the superior qualities of meat: it is attractive to the eye, has a pleasing odor when cooked, adds interest and flavor to the diet, and is palatable, healthful and highly nutritious. Let us briefly consider its nutritive value.

Being high in readily digestible protein, meat builds and repairs body tissues and is important in preventing and curing anemia. Liver and kidney, heart, and skeletal muscles are valuable in hemoglobin formation. The red blood pigment contains iron that, in the presence of adequate proteins, vitamins (*9*) and certain other nutrients, is essential to such pigment building.

Meat also contains various elements essential to growth and health. It is high in phosphorus—important in the building of skeletal tissue—and contains traces of aluminum, copper, manganese, magnesium, and zinc which seem to have a favorable reaction on the human system. Cooked beef, lamb, and pork are relatively rich in thiamin (vitamin B_1) and riboflavin, and they contain a trace of vitamin A but no ascorbic acid, that is, vitamin C (*1*, *2*). Liver is particularly rich in vitamin A. The fats are a cheap and important source of energy.

Undoubtedly range management and the products of the range are prominent factors in a balanced agriculture of the world. By trans

forming range forage into vast quantities of critically important human food, the livestock industry stands high in its service to mankind

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THE WORLD'S GRAZING PRACTICES AND PROBLEMS

What are the best uses of pasture areas This question is likely to be asked in all countries of diversified land management practices In the older settlements of the world most of the lands have been put to their best economic use chiefly through trial and error methods In

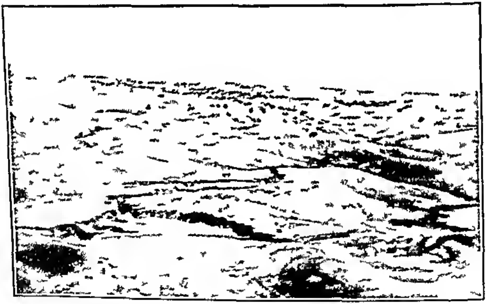

FIG 3 Formerly good range land that was plowed and seeded to grain during World War I When the topsoil had eroded away and numerous gullies had formed, the land was abandoned to revert to inferior volunteer annual grasses and weeds (Tehama County California)

the younger settlements the agricultural ventures are still in progress and account for the changing land practices too commonly found in many parts of the world

Broadly speaking agricultural land users may be divided into three groups (1) The strictly crop farmers They occupy the better lands,

their settlement is relatively compact, the agriculture is stable, and markets are close at hand (2) The combination crop farmers and stock raisers They occupy the somewhat hillier, medium priced land, the settlement is less compact, markets more remote (3) The exclusive stock raisers They occupy the hillier, drier, and lowest priced land where population is sparse and markets remote

Next to the borderlands worked by crop farmers are sometimes sub marginal farm lands They are generally occupied by the graziers, as in western United States, but the choicest portions can be farmed with varying success during periods of high rainfall and favorable economic conditions These crop farmers usually grow grain, are here today but gone tomorrow, and have destroyed many of the grazing resources in parts of nearly every continent With each wet cycle and economic boom more virgin grassland is broken up (Fig 3) Clearly, most semiarid lands that are devoid of irrigation water serve man best where the sod is preserved for grazing (*13*)

Continental Considerations

In the following analysis of livestock production on all continents we consider the importance, stability, and probable future expansion of the industry in all areas of the world Also discussed are the handicaps to be overcome and the contributions made by the various countries to the livestock industry as a whole and to the graziers of North America in particular Knowledge of these facts should be helpful in avoiding repetition of mistakes and in learning from the experiences of others

Europe

This is the smallest of the old-world continents, with an area of 3,750 000 square miles and, excluding Russia a population of 402,800 000 To facilitate discussion, Europe is divided into four numbered ecological and economic regions (Fig 4)

I *Northern Region* includes most of Norway, Sweden and Finland and extends eastward to the Ural Mountains Because of the short summers and long winters, it is not intensively developed agriculturally Yet dairying in parts of Scandinavia is both intensive and specialized The Finns have developed a small, white, good milk-producing cow that endures intense cold and may become useful in Alaska The long winters requiring large quantities of supplemental feeds, have created a strong demand for cottonseed cake from the United States. Reindeer production of northern Finland, Sweden and Russia has possibilities of further expansion The animals are largely

Fig 4 Relative distribution of cattle and sheep in the four ecological regions of Europe shown by density of shading

owned and reared by the Lapps. The governments control the grazing intensity of much of the tundra as a precaution against overgrazing.

II. *Lowland Plains Region* includes Great Britain, Ireland, France, and the land belt eastward to the border of Asia.

The British Isles have little soil erosion and, because of the cool, damp climate, have green pasturages throughout the year. They are well known as the land of origin of such breeds of beef cattle as the Aberdeen-Angus, Galloway, Hereford, and Shorthorn; of such long-wool breeds of sheep as the Cotswold, Leicester, Lincoln, and Romney; and of medium-wool breeds such as the Cheviot, Dorset, Hampshire, Oxford, Shropshire, Southdown, and Suffolk.

The British Isles also have domesticated many forage plants, notably Canada bluegrass, Kentucky bluegrass, meadow fescue, orchard grass, ryegrasses, timothy, and such forbs as clover and burnet. Much of the pasturage is used to produce high-quality beef and mutton, since most of the dairy and pork products are imported from Denmark and New Zealand. The area maintains nearly ideal grass and legume pasture mixtures through the use of soil fertilizers. Present pasture fertilization technology in North America is essentially based on England's findings.

The other western nations—Denmark, Belgium, France, Germany, Holland, and the southern part of Norway and Sweden—raise fairly large numbers of livestock, mostly on farms of 10 to 20 acres. France has developed the Rambouillet breed of fine-wool sheep, using the Spanish Merino as the foundation breed. Denmark, Holland, and Belgium probably have the most highly developed dairy industry in the world. The damper areas of this region have eroded little, but some of the drier, thinly vegetated lands of southern Germany and interior France have eroded severely. These areas are now being conserved by ingenious engineering works and by planting to trees, shrubs, and grass.

The central nations of this region—Czechoslovakia, Poland, and western Russia—have a primitive agriculture and inferior livestock. Before World War II about half of the land area of Poland was owned by 3 percent of the people, a condition that contributed tellingly to the poverty of the masses. The sheep are light-shearing and small, consisting mostly of fat-tail, Karakul, and Merino blood. The extensive prairie of southern and central Russia is ideal for cattle and fair for sheep. Goats are increasing in population, both on individual farms and on the large collective ranches that were acquired by the Greek Catholic Church during Czardom and confiscated after World War I by the revolutionists. Much of northern and eastern Russia, despite

the extensive coniferous forests is suitable for cattle and sheep grazing, and livestock numbers can be expected to expand. Erosion has been severe in some parts, particularly in southern Russia, where the effectiveness of shelterbelts in stabilizing the soil is being studied.

III. *The Mediterranean and Balkan Region* includes the nations from Portugal and Spain eastward to Greece and Roumania. It is a region of dry, mild climate with diversified vegetation. Large areas of the wild lands of Greece, Italy, Spain, and Portugal have long been over-utilized by goats and other stock. In parts of Greece milk sheep are replacing goats, the hope being to decrease overgrazing. Spain must be credited with developing the popular and widely distributed Merino breed of fine-wool sheep. In this region agricultural practices are primitive. Oxen and water buffalo are used for work, and in many sections livestock is of inferior breeding. Several annual forage plants and noxious weeds of this region have been accidentally introduced into and naturalized in California and adjacent states. The most common forage species so introduced are bur clover, filarees, annual fescues, and wild oats. In this region also, Ladino clover was perfected.

IV. *The Steppe Region* includes the southern short-grass portion of a region that is nearly ideal for cattle and is fair for sheep. When better blood is used and diseases are better controlled, animal production of this region should increase markedly. The grasses are nutritious, and the climate is healthful. With improved transportation, ample markets would be available for the animal products.

Possibilities of livestock expansion in Europe are distinctly regional. Although the continent has a large livestock population, more meat and hides are needed. Future possibilities of livestock expansion appear insufficient for the continent to become self-sustaining in meat requirements. The western nations are evidently fully stocked, but in Russia and the Balkans more animals could be raised if diseases were better controlled. Region II and Region IV of Russia (Fig. 4) have the best potentialities for increasing their livestock numbers.

Asia

This is the largest and the most heavily populated of the continents, with an area of 17,000,000 square miles and with some 1,154,000,000 people. Asia has many cattle and fair numbers of sheep, despite their absence in the northland and their scarcity in parts of the west. The continent is divided into five numbered ecological and economic regions (Fig. 5).

I. *The Siberian Region* encompasses the Asiatic portion of the Soviet Union, of which a large part is similar in climate and vegetation

to northern United States and Canada but is undeveloped and sparsely populated. Despite the long, cold winters, southern Siberia is a healthy country and a potential cattleman's paradise (22). Extensive prairie land covered with wheatgrasses and ryegrasses provides excellent forage. Some regions support forage plants that have become broadly useful. Among these is crested wheatgrass of the Ural Mountains, which is

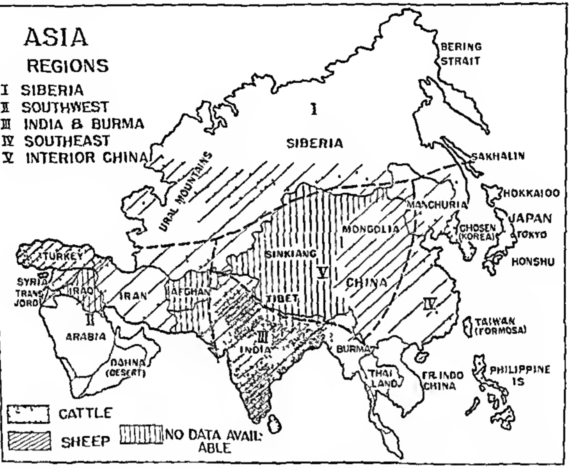

FIG. 5. Relative distribution of cattle and sheep in the five ecological regions of Asia, indicated by density of shading.

popular for pasturage in western Europe and western North America. But the Siberians could use more and better livestock. A small part of the demand for meat and hides is supplied by the nomadic reindeer herds of the adjacent tundra, and this herding is capable of some expansion. This area could become the granary of Europe and an impressive meat-producing region when the now inadequate transportation system is improved.

II. *The Southwestern Region* extends from Turkey and the Arabian peninsula eastward to India and southwestern Siberia and has a dry climate with warm summers and fairly mild winters. Steppe vegetation alternates with brush. Turkey has the heaviest livestock popu-

lation including many Angora goats Arabia continues to enjoy a high reputation in horse breeding other districts raise superior camels, but the desert prevents extensive rearing of cattle and sheep The animals are poorly handled and much of the country is overgrazed It is unlikely that the livestock industry will expand

III *The India and Burma Region* is densely peopled, dependent on agriculture and much influenced by traditions Dating back to about 3500 B C India s civilization carries with it deep rooted customs, many of which appear irrational from the standpoint of livestock utilization and production Religion enters strongly into the dietary habits of the people The 325,000 000 Hindus, including the 50,000,000 Untouchables for example do not eat beef, the 100 000 000 Mohammedans do not eat pork but both may enjoy mutton and lamb, though they eat little meat (29) Milk and its products supply most of the dietary protein Despite the wastage of animal flesh, cattle in India and Burma are tremendously important, supplying nearly all power for road transportation and for cultivation of the farmlands The cattle are of the Brahman or Zebu, breed (*Bos indicus*) Their inferior quality and small milk production are due more to malnutrition than lack of breeding At present, each 100 acres of cultivated land in India supports 67 cattle If this number were reduced by one half and were handled in a modernized manner India could greatly increase its milk supply and work potential But the sentiment against killing of cattle is so strong that even the old, sickly animals are pampered and sustained on forage needed for the productive herd The widespread rinderpest and foot and mouth diseases cannot be stamped out or controlled because contaminated animals may not be destroyed Partly because of poor sanitation Brahman cattle have built up remarkable resistance to disease, including that carried by the tsetse fly This fact and their adaptability to warm humid climate has made Brahman cattle popular in the Philippine Islands in tropical regions of South America Australia and Africa, and in parts of southeastern United States Although the pastures in India are overcrowded, soil erosion is only moderately serious partly because of the presence of native sod forming species such as Bermuda grass Improved strains of Bermuda grass are now being grown in southern United States and in other mild humid climates

IV *The Southeastern Region* includes China proper, eastern Manchuria, Thailand Japan and the Philippine Islands About 80 percent of the Chinese people live on farms The land is intensively used, but practices are primitive and wasteful About 5 percent of the tillable land is taken up in burial grounds Besides many hogs and fair numbers

of sheep, China has many cattle and water buffalo (*Bos bubalus*) which, incidentally, furnish most of the farm power but are not extensively milked

Eastern Manchuria, as yet largely undeveloped and statistically almost unknown, apparently has few cattle and almost no sheep Siam has many Brahman cattle The Philippine Islands are covered with hardwood forest and support only a few cattle, mostly of poor quality Rinderpest is a serious disease Japan also has few livestock, for the more accessible lands are farmed intensively On the humid, mild-climated Island of Hokkaido, sheep raising has been tried out with varying success

Since the Japanese islands receive 40 to 60 inches of rainfall a year, the resulting dense vegetation effectively protects the wild lands from conspicuous erosion On the steeper cultivated land, terracing has conserved the soil In contrast, much of China's land has eroded severely, though some corrective work has been done In southern China, where rainfall is heavy and the farm lands have not been terraced, many hillsides are depleted, in the central portion, where rainfall is intermediate and the plant cover less dense, severe erosion is more general, in northern China, where rainfall is light, erosion of the soft loess soil has been severe despite extensive terracing (*3*)

V *The Interior China Region* embraces the sparsely populated provinces of Mongolia, Sinkiang, and Tibet The rainfall is generally light, the summers are hot, and the winters are cold Little authentic information is available to convey a picture of the populations or distribution of the cattle and sheep Sections of Mongolia are peopled by native nomads who subsist largely on meat and whose religion denies them disturbance of soil other than by heavy grazing The resulting destruction of the plant cover is exceeded only by the dry-farming practices of itinerant Chinese farmers of the region The plowed fields, abandoned during dry cycles, suffer severely from sheet erosion and contribute to the extensive dust storms The more rugged areas of Sinkiang and Tibet support fat-tail sheep, cattle, yaks (*Bos grunniens*), and goats that subsist yearlong on the natural herbage Most of the animal products are used locally (*28*)

Expansion of livestock, except for reindeer in the far north (Region I, Fig 5), seems remote This is also true for India and Burma, because of religious tradition China proper has such great need of cereal crops for human food that livestock expansion appears improbable Interior China has good grazing grounds, hence the industry could expand if markets and transportation were improved The two greatest con-

tributions of this continent to the livestock industry as a whole are Bermuda grass and the heat resistant Brahman breed of cattle.

Africa

This is the second largest continent with an area of 11,710,000 square miles and with 157,330,000 people. The vast, inhospitable deserts and tropical jungles account for the uneven distribution of livestock. The people are essentially pastoral, for only 10 percent of Africa is forested. Most of the animal products are used locally. The small size and inferiority of the livestock population are caused by diseases, poor blood lines, inadequate transportation, the numerous large game mammals that complicate livestock handling, and low living and educational standards. The continent of Africa is discussed under five numbered ecological regions (Fig. 6).

I. *The Congo Basin Region* is wet and tropical and supports the continent's largest hardwood forest (*38*). The Congo jungle presents obstacles of diseases and unfavorable climate that are too great for the rearing of livestock.

II. *The Savannah Region* is transcontinental and extends from the west coast of French West Africa eastward across the continent and south to Northern Rhodesia. Except for the drier portions of the desert, the region is essentially savannah, with wide variations in rainfall and temperature. The densest livestock population is concentrated in the eastern territories where the soil is fertile and the rainfall fairly heavy. This region presents three outstanding problems: (1) many large mammals, especially antelope, hartebeests (*Bubalis caama*), and zebras (*Equus zebra*), which consume much forage and preclude effective use of fences, (2) diseases, notably rinderpest, a contagious fever plague among cattle, and sleeping sickness, caused by a parasite carried by the dreaded tsetse fly (*Glossina palpalis*) and fatal to man and domestic stock (it has been brought under control recently by immunization with a drug called *antrycide*), and (3) mineral deficiencies of the forage which, in some areas, must be overcome artificially.

III. *The Desert Region* is a transcontinental desert and lies between the states in the extreme north and the savannah in the south. Most of this dry, hot region precludes adequate forage growth. Livestock are found primarily along the Nile River in Egypt.

IV. *The Mediterranean Region* includes the extreme northern portion of Africa; it has a rainy season from October to June and hot, dry summers. Climatically and floristically this region is similar to much of California. Annual species associated with shrubby growth furnish

most of the forage. In summer the grazing season is supplemented by stubble pasturage and, in some areas, by bur-clover, lespedeza, and alfalfa (*14*). Because of lack of reservoirs, water is seasonally deficient.

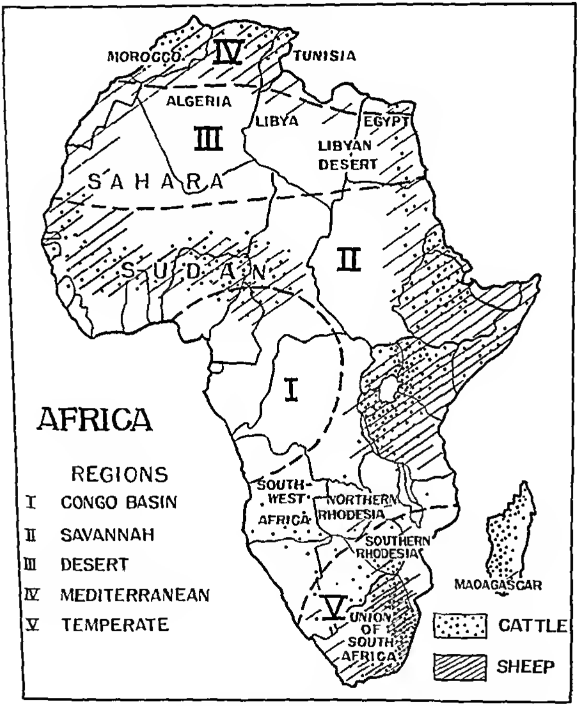

FIG. 6. Relative distribution of cattle and sheep in the five ecological regions of Africa, indicated by density of shading.

Algeria and Morocco have many inferior and poorly managed cattle, sheep, and goats. According to Killough (*21*), anthrax and contagious abortion are the most troublesome diseases; but the heaviest stock losses

result from malnutrition The people, predominantly illiterate Arabs of low living standards due to lack of economic and educational opportunities are themselves the main obstacle to livestock production

V *The Temperate Region* includes Southern Rhodesia, the Union of South Africa and Madagascar The climate of mild winters and warm summers is compatible with satisfactory seasonal distribution of the 15 to 40 inches of rainfall The northern portion and Madagascar are cattle country whereas the southeastern portion raises both cattle and sheep The meat and hides are mostly traded with Great Britain The grazing capacity of the better managed Union veld is fairly high, but many areas are overgrazed The drier, tick-infested veld, as in the Transvaal, is pastured by the hardy, strong-footed, thick-skinned, native or Afrikander type of cattle—evidently of Brahman foundation This breed is being tested for adaptability in southeastern United States and elsewhere In the Transvaal the Afrikander cattle outnumber all other beef breeds except the Shorthorn Merino and fat tails are the most popular breeds of sheep Handicaps in livestock production, other than drought, are inability to maintain fences because of numerous large native mammals, the protective practice of *kraaling* (corralling) the stock at night, the necessity of herding on foot because of a common horse sickness, phosphorus deficiency that necessitates feeding of bone meal, land speculation and plowing of the veld, which has resulted in destruction of needed forage, unfavorable plant succession resulting from burning and from erosion around the *kraals*, and only passive interest in ranching because of attraction to the gold and diamond mines (*5, 11, 33, 35, 36*) From this region have been introduced into the United States species of native lovegrasses (*Eragrostis* spp), which are being used successfully to revegetate ranges in southwestern United States, and Harding grass (*Phalaris tuberosa* var *stenoptera*), a useful species in the Pacific Coast states

Possibilities of livestock expansion in Africa are poor The small world trade in her livestock products is not likely to expand in the near future because of seemingly insurmountable handicaps The best possibilities of livestock expansion are in the Mediterranean region IV (Fig 6) and in the Temperate region V

The Southwest Pacific Countries

Australia, New Zealand, Tasmania, and the adjacent tropical islands on the north are included here Since Australia and New Zealand produce most of the livestock, the discussion is chiefly confined to those countries

Australia This relatively level continent, with an area of 2,974,500 square miles, is only slightly smaller than the United States and has a population of about 8,000,000 (Fig 7)

Except for the tropical northern portion, Australia enjoys a temperate to subtropical climate The rainfall, which has strong cyclic and distributional variability, has profoundly influenced the uses of the land and the distribution of the inhabitants The northern area has

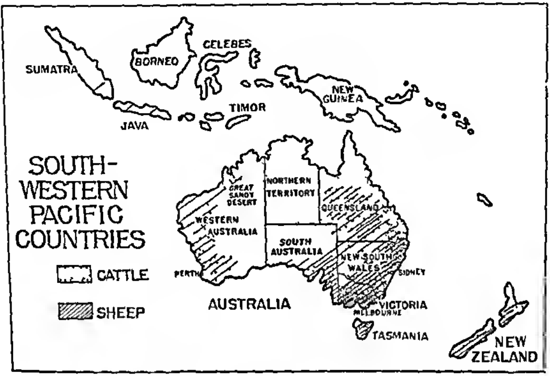

Fig 7 Relative distribution of cattle and sheep in the Southwest Pacific countries indicated by density of shading

rainy summers, the southern region has rainy winters and both have prolonged dry seasons Highly important areas for livestock and farming are the southeastern portion of South Australia eastward to the coast of Victoria, New South Wales, the southern half of Queensland, and the coastal strip of Western Australia (Fig 7) Oatgrasses (*Danthonia* spp) and needlegrasses (*Stipa* spp) were originally abundant on areas receiving annual rainfall of about 20 inches Several million acres of these more favorable rainfall areas were the first to be grazed by domestic stock The better of these moderately high rainfall units were fertilized with superphosphate and nitrogen and then seeded with perennial ryegrass (*Lolium perenne*), subterranean clover (*Trifolium subterraneum*), and Harding grass (*Phalaris tuberosa* var *stenoptera*), alkali areas were seeded with medics (*Medicago* spp) This practice has conspicuously increased grazing capacity and im-

shown promise of successful suppression (*15*). In 1945 the first species of *Chrysomela* were introduced from Australia into California, to determine their effectiveness in controlling the local St. Johnswort (Klamath weed) pest. Certainly Australia provides impressive examples of the caution other countries should take in introducing animals and plants. On the other hand, this nation has demonstrated the great benefits that can accrue from introductions of suitable range plants.

New Zealand. This isolated, healthful country of 104,000 square miles (Fig. 7) is about the size of Colorado and has a population of 1,750,000. The precipitation ranges from 60 inches in the North Island to 30 inches in the South Island; and since it is rather evenly distributed, green forage is available yearlong. Climatically it is probably the most efficient and highly favored pasture country in the world, Great Britain ranking second in this respect. Sheep raising constitutes the real wealth of the country, but dairying and beef production are also important. The Romney, Lincoln, Merino, and Corriedale—Corriedale evolved locally and now raised in western United States and other temperate countries—are the popular sheep breeds; Shorthorns and Aberdeen-Angus are the most common beef breeds. New Zealand is a country of small ownership, the bands mostly numbering from 400 to 1000 mature sheep. Originally much of the North Island was forested, but the trees have been largely replaced with sod-forming English bentgrasses, bluegrass, and subterranean clover. The cover is kept closely cropped by alternate grazing. Mineral fertilizers are used extensively to enhance pasture growth. On hilly land, where the tussock is frequently burned, erosion has been severe. Zotov (*39*) concludes that fire is the primary cause of the depletion. During World Wars I and II, much of the remaining high-quality timber land was burned to convert it to pastures. But the attempt proved a failure, for the lands have reverted to brush, and nearly all required lumber must be imported.

The most troublesome animals are the English rabbit, the hare, and the fox; and among the introduced plants, St. Johnswort is the worst pest (*12*).

Possibilities of livestock expansion in Australia and New Zealand are good. In spite of severe periodic droughts and destructive animal and plant pests, Australia may impressively increase her livestock populations. Maximum expansion, however, must await improved land transportation. This is true also of New Zealand, whose industry is less subject to depressive droughts.

South America

South America with an area of 6,800 000 square miles, is essentially an agricultural country The population of 110 000 000, which is less than half that of North America, is largely agrarian Nearly two-

Fig. 8 The relative distribution of cattle and sheep in the four ecological regions of South America, indicated by density of shading

thirds of the continent is tropical, but large areas are tempered by elevation, trade winds, and sea currents Livestock production, a primary industry in several regions, is discussed under four numbered ecological and economic regions (Fig 8)

I *The Southern Plains Region* is bounded on the north by Brazil and Bolivia and extends southward to Tierra del Fuego, eastward to the coast, and westward to the Andean mountains of Chile The climate is mildly temperate, and the generally well distributed rainfall ranges from 60 inches in Paraguay and adjoining territory to 10 inches

or less in Patagonia. The Republic of Argentina, which comprises most of this region, is a highly important livestock country. Large numbers of cattle and sheep abound in the province of Buenos Aires, as well as in Uruguay and in southern Brazil. The Patagonian desert southward to Tierra del Fuego is essentially a sheep country. Large areas of the native hard grasses have been replaced by nutritious, domesticated European species and by locally improved endemic species, notably Dallis grass (*Paspalum dilatatum*) and rescuegrass (*Bromus catharticus*)—now used in range reseeding in the United States—and by alfalfa.

In most of Argentina and Uruguay the cattle are well managed and of good quality, but southern Brazil has a poor quality of badly handled cattle, and there is little effort to curb diseases. Throughout this region the *criollo* (native cattle) have been replaced by Shorthorn, Hereford, and Aberdeen-Angus; and the original small Spanish sheep have given way to the Lincoln, Romney Marsh, and Merino. In some parts of this region foot-and-mouth disease, Berne fly, and fever tick are troublesome. Erosion has not been extensively destructive, although in arid La Pampa and westward from Buenos Aires wind erosion has been destructive.

II. *The Savannah Region* is composed of two units of similar vegetation: the large Brazilian savannah and the smaller, intensively tropical Venezuelan and adjoining Guianan savannah. The annual rainfall of about 60 inches comes mostly in spring and summer and favors luxuriant plant growth. The ranches are large and poorly managed; the cattle are disease-ridden and of poor quality but are being improved by Brahman bulls. Overgrazing and frequent burning have caused destructive erosion in northern and eastern Venezuela and in parts of the Brazilian region. Both nations are now demonstrating soil stabilization techniques by planting to trees and grasses (*4*). Several locally improved endemic species of *Paspalum* contribute to the forage crop, especially Dallis grass, Bahia grass (*P. notatum*), Vasey grass (*P. urvillei*), and *P. malacophyllum* (*8*).

III. *The Amazon Basin Region* is an extensively tropical savannah country of heavy rainfall. Much of this region is so favorable for growing coffee and sugar-producing crops that livestock grazing is neglected. Only the less heavily wooded eastern portion is moderately suitable for livestock raising. Tick fever, Berne fly, and foot-and-mouth disease are troublesome. The cattle are given little care, and though improved by Brahman bulls they must be sold as canners or be converted into extract. The long, hard drive to market drastically reduces the quality of the beef.

IV *The Montane Andean Region* extends from western Venezuela southward and is a relatively undeveloped stock-raising and farming province of good livestock potentialities The coastal and mountainous strip from Colombia to southern Chile is suitable for livestock Colombia is fairly typical of the north coastal strip, which also includes Ecuador and Peru Cauca valley in southeastern Colombia is highly productive and supports fair numbers of unimproved stock Herd and range management are almost unknown, little is done to check such common diseases as blackleg, foot-and-mouth, and the tick fever Soil erosion is severe in many places but some protective forest zones have been established under governmental supervision

In Chile, cattle and sheep are especially important in the central valley The animals are better bred and cared for than they are farther north In north Chile alternating droughts and floods cause an erosion problem The government is attempting to curtail erosion by planting trees, educating people in improved farming methods, and encouraging conservative livestock grazing

Possibilities of livestock expansion is best in the Southern Plains region (I, Fig 8), Argentina having the greatest possibilities of livestock expansion Because of the dry climate and sparse vegetation, sheep will probably continue to hold first place in the Patagonian desert and southward Uruguay probably has reached maximum production in livestock numbers This leaves Brazil in second place in potential livestock expansion and Chile third But tropical Brazil and other northern countries have too many handicaps and cannot expect much livestock expansion in the near future

North America[1]

This continent, next in size to Africa and Asia, has an area of 8,665,000 square miles Its population of 200,000,000 is exceeded only by those of Asia and Europe North America is a continent of contrasting climate and vegetation The far south is characterized by tropical rain forest, jungle, savannah, and hot desert, the far north by tundra, swamp, and pockets of dwarf trees (*38*) Between these extremes are vast areas of forests, prairie, plain, and desert, with extensive tracts converted to farms and improved pastures Although it is rich in natural, renewable resources, this continent has contributed no domesticated foraging animals or range plants useful in other parts of the world North

[1] For purposes of consistency North America is treated as broadly as the other continents discussed here Chapter 5 treats of the more detailed physical and biological features of the United States as they relate to pasture management

America is divided into four numbered ecological and economic regions (Fig 9)

I *The Tropical Region* embraces torrid Mexico and the Central American nations from Guatemala to Costa Rica, and the islands of the Carribean The tropical heat is partly tempered by the Rocky Moun-

Fig 9 Relative distribution of cattle and sheep in the four ecological regions of North America indicated by density of shading

tains chain which extends into and beyond Nicaragua, and by the heavy, fairly evenly distributed rainfall Cleared jungle and open savannah provide the chief grazing ground Although livestock are not numerous, fair populations of cattle and sheep occur in Mexico and Honduras, whereas from Nicaragua southward only cattle are reared Inertia of the people and political unrest have contributed to the laxity in the livestock industry Sanitation is poor, diseases are little controlled, transportation is inadequate, the animals are of inferior blood, and soil erosion is severe as a result of overgrazing and excessive burning In recent years Honduras and Nicaragua have given more

attention to improved range and livestock management than other countries of this region and are exporting considerable amounts of meat to their neighbors (23)

11 *The Humid Eastern Region* is the relatively level country that lies essentially east of the 100th meridian. The region includes the eastern half of southern Canada and the eastern half of the United States (Fig 9) The warm, humid summers are tempered by frequent rains, but the winters are long, cold, and snowy, except in the mild-climated southern states The annual precipitation is fairly evenly distributed through the year and ranges from 25 to 35 inches in the midwestern tall-grass prairie to 60 inches or more in parts of the deciduous and coniferous forests of the East and South. Generally, the grazing capacity is high.

Dairying is the most important livestock enterprise near the large industrial cities, but hogs and some beef cattle are produced, mostly on pastures seeded to domesticated grasses and legumes. The southern states have a fair population of beef cattle of medium quality and some hogs but few sheep. The animals graze on farm fields and in the piney woods whose undergrowth is frequently burned (Chapter 15). Although much of the South has been freed of the fever tick, some tracts are still subject to governmental tick quarantine regulations. During the last quarter century breeding to Brahman bulls has improved the hardiness of the southern cattle.

Westward, in the highly productive corn belt (the midwestern interior lowlands) extending roughly from the Dakotas and Ohio southward to the cotton belt, lies the greatest livestock-fattening area of the world. Each autumn and winter great numbers of cattle and sheep are shipped in from the western and northern range country to midwestern livestock commission houses, where they are sold to the farmers. The animals are fattened to prime condition on corn and on hay of alfalfa, clover, or prairie grass. When market-fat they are sold to local packing houses. Important as this industry is, hog production ranks first. The hogs are run as scavengers along with the cattle to consume undigested or otherwise wasted corn. The grazing capacity of the pasture lands is high. Two to five acres on the better lands are sufficient to maintain a mature cow for the normal 7-month season.

Few troublesome animal or plant pests occur in this region. The sheep-killing dog is the worst predator, and unpalatable weed invasions diminish the pasturage. Among the diseases, blackleg, contagious abortion, and tuberculosis cause varying losses; in the South, tick fever requires attention.

Soil erosion demands correction in several localities. Erosion is most

widespread in the Appalachian Mountains and Plateau, but it is locally more destructive in the middle and south Atlantic section where it is rated as the most critical single physical problem (*3*). In the central prairie country, erosion is most severe in northern Missouri, southern Iowa, southeastern Nebraska, northeastern Kansas, and on the hardpan soils from southern Illinois to northeastern Oklahoma. Corrective measures are under way in many communities.

III. *The Arid Western Region* extends from southern British Columbia east to Manitoba, south into eastern Mexico, and west to the coast; it embraces vast grazing commons. The region lies roughly west of the 100th meridian between elevations of 2000 feet in the plains country to 10,000 feet or more in the mountains. The summers are generally hot and the winters cold, except along the Pacific slope, in the southwest desert, and in Texas. In these areas the summer temperatures are high (except along the humid coastal strip), and the winters are mild. The region varies from semiarid to arid. Adequate stock water is frequently a factor of concern. The food plants are mostly composed of perennial drought-enduring grasses, forbs, and shrubs. The grazing capacity varies from some 15 acres per animal unit for the normal grazing season in the Great Plains to 100 acres or more in the southwest desert.

Among the predators, coyote, bobcat, lynx, cougar, wolf, and bear are most troublesome. Also, various poisonous plants cause heavy, localized livestock losses each year (*27*). In the southeastern part of Region II and in the coastal and southwestern parts of Region III, brush invasions are so troublesome that many stockmen are induced to fire the lands (*31*, *32*, *37*) (Chapter 13). Mineral deficiencies and seasonally inadequate forage nutrition require consideration in some areas. Despite these handicaps, a large part of the total cash income is from range livestock.

A comparison between the eastern and western regions of the United States shows that there are more cattle but fewer sheep in the East (Fig. 10). For beef cattle, the ratio East to West is 1.9 to 1, for dairy cattle 7 to 1, but in sheep the West leads, with a ratio of 0.7 to 1. Allowing 5 sheep as equivalent to 1 cow as 1 animal unit, the East has 56,640,000 animals units to the West's 21,060,000 animal units, or a ratio of 2.7 to 1.

Over parts of the range country soil erosion has been severe. On overgrazed areas of the Great Plains region, for example, where the prevailing wind velocity is the highest in the nation, soil blowing and washing have been destructive; in the Great Basin country, accelerated erosion has become a major problem over three-fourths of the range

area, and in the southwest desert erosion has caused great depletion (3) Contributing to the devastating erosion has been the breaking of the sod this was done in parts of the semiarid Great Plains, California, and the Northwest during periods of high grain prices or favorable precipitation cycles Regrassing has resulted in stabilizing some of these areas An extensive program of erosion control awaits action

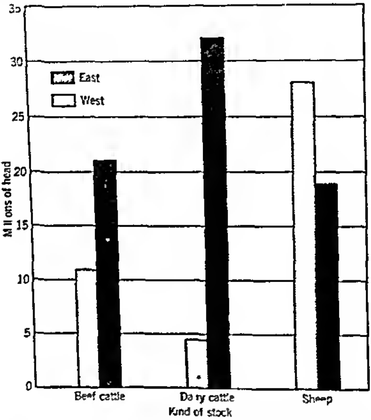

FIG 10 Numbers of beef cattle, dairy cattle and sheep in the eastern and western halves of the United States as divided by the 100th meridian. 1940

IV *The Arctic Region* includes the vast boreal coniferous forest association and tundra formation from British Columbia and Alaska eastward to Greenland and south to Labrador and Ontario Almost uninterrupted daylight and nearly continuous night divide the year The amount of precipitation varies greatly and is highest along the coast. This region, characterized by a growing season of only about 2 months, nevertheless, broadly considered, supports three major plant associations coastal forest, boreal interior forest, and the treeless, prairielike cover of the true arctic and subarctic zone bordering on the Bering Sea and the Arctic Ocean (26) The tundra is less stable

in the moist regions than in the drier ones; the lichen and moss cover sometimes require half a century under total protection to recover from injury through fire or overgrazing. In contrast, open herding and conservative grazing provides sustained utilizatinn of the tundra vegetation.

Few sheep and beef cattle are grazed in this region. On the Alaskan and Canadian tundra, reindeer, now being improved by crossing with the caribou (*Rangifer caribou*), afford an expanding nomadic enterprise. Initially, 10 reindeer were introduced from Siberia in 1891. From these and a few, small, later importations, the American herd increased to some 400,000, most of which were owned by the Eskimos (*24, 25*). In recent years reindeer have declined in numbers as a direct result of wolf depredatinns and lack of care.

Possibilities of livestock expansion in the continent seem favorable in but few regions. Tropical America (Fig. 9, Region I) is taking care of its demands for meat and hides fairly well. Honduras and Nicaragua have the best immediate probabilities of livestock expansion. Ultimately, tropical Mexico should become a more important livestock country. The humid central and northeastern unit of Region II has apparently reached the saturation point in production and fattening of cattle and sheep, but hog raising in the corn belt may expand. The southern unit of Region II seems certain of increase in population of beef cattle as better blood is introduced, as the diseases are more effectively controlled, and when pasture forage is improved. The arid west (Region III) will continue to supply large numbers of quality feeders to the midwest, but appreciable expansion in livestock numbers seems improbable despite some irrigation and local success in artificial reseeding of depleted ranges. In the Arctic country (Region IV), the reindeer industry offers some possibilities of expansion. Its permanency hinges upon conservative winter grazing of the lichen and moss lands, some of which are readily depleted and recuperate slowly.

Ratios of Livestock Numbers and Human Populations

The ratios between human and livestock populations of the various countries frequently accounts, among other things, for the extent of importing or exporting of meat by these nations (*11, 16, 17, 18, 19, 34*). The most convenient way to indicate the home supply of a country is to compare the ratio of animal numbers to the human population.

In the ratio of sheep per person New Zealand is first and Australia second, Uruguay third, Argentina fourth, the Union of South Africa

fifth, Brazil sixth, and the United States seventh. New Zealand ranks first in sheep both in density (310 per square mile) and in ratio of sheep to the human population (20 to each person). In the ratio of cattle Uruguay is first and New Zealand second.

Climate and Livestock Distribution

Through trial and error it is now recognized that certain species and breeds of foraging animals are best adapted to fairly specific climatic regions. In tropical countries Brahman cattle do exceptionally well, in temperate climates European breeds of cattle are best, in semidesert regions goats and fine-wool sheep are most economical, in the tundra reindeer and caribou are the exclusive domesticated ungulates, in warm, humid marshes the water buffalo is at home. Environmental adaptation has literally resulted in a 'climatic stratification' of species and breed distribution (30). Fortunately, highland breeds are now less frequently placed on low areas, and northern breeds are less often raised in the humid tropics, also, the smaller breeds are more generally selected to graze on sparsely vegetated pasture.

The reason why animals become adapted to distinctive climates lies essentially in their anatomical and physiological make-up. This is well illustrated in Brahman and European cattle. Kelley (20) has shown that the temperature of European cattle is highest about noon and that the febrile state continues until the atmospheric temperature drops in the evening. In contrast, the body temperature of Brahman cattle rises but slightly during the midday heat and is quickly lost as the air temperature drops, partly because they have a slower pulse than European cattle. Also, the well developed sweat glands of Brahman cattle exude large quantities of fluid, which cools the skin and body by evaporation. European cattle have only rudimentary sweat glands and have all but lost the capacity to perspire, instead they freely eliminate water vapor through the lungs. In the tropics the tongues of European cattle are commonly extended and drip "saliva," whereas the respiration rate of intermingled Brahmans is only slightly increased. Kelley further notes:

> When in the tropics, European cattle have abnormally low hemoglobin indexes, whereas those of Brahman are equivalent to the indexes and red-cell counts of European cattle in temperate climates. The resulting changes operate adversely on the general constitution of the animal body, making it incapable of adjusting itself to environments with high temperature.

Brahman cattle are more resistant to high temperatures than British cattle, this partly accounts for their adaptability to the tropics. Brah-

man cattle have much skin surface, short hair, light surface-skin color, deeply pigmented skin underneath, and a thick hide. Short hair favors greater body heat elimination and gives less protection to ticks. Light hair color throws off much of the intensive solar radiation, as compared with deep color or a black coat. Also, the deeply pigmented skin underneath the hair-coat cells of Brahmans impedes penetration of strong solar rays and prevents skin burn. However, in localities where the native or Brahman cattle are below the environmental (climatic) potential, crossing with English breeds offers possibilities of improvement (*30, 31*).

One of the complications encountered when livestock adapted to a relatively cool region are brought into warm climate is that of procuring reproduction. Most livestock breeds adapted to temperate climates tend not to mate during the hotter period, whereas warm-climate breeds will mate at any season. Flushing the animals, by reserving lush pasturage for the breeding season, is helpful. In the Gulf Coast strip of the United States the Brahman × Shorthorn cross has added vigor and has increased the calf crop (*6*). The Santa Gertrudis, a cross between the Shorthorn and Brahman, is becoming popular in coastal Texas where it has been perfected (*30*). In tropical and semitropical India, Brazil, Jamaica, and the Philippines, Brahman blood has been effectively introduced into dairy herds (*22*). At the other climatic extreme an effort is being made to perfect a cross between the yak and the bison (*Bison bison*) for grazing on cold Alaskan and Canadian ranges.

Climate also profoundly affects the character and amounr of forage produced. Chapline and Cooperrider (7) found a direct correlation between the average annual precipitation and forage production.

Sparse forage growth, especially where the topography is rough, calls for employment of those breeds of livestock that can utilize the pasturage to best advantage. The hardy Hereford cattle—of strong "rustling" qualities—and the lighter-bodied, fine-wool sheep, are well suited for such areas. On the other hand, in the productive midwestern United States, Shorthorn cattle, with large capacity for food, and the heavier breeds of medium- and long-wool sheep are favored. Further intelligent selections and matings of species and breeds of livestock for specific climatic areas offer good economic possibilities.

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PHYSIOLOGICAL PRINCIPLES AS APPLIED TO RANGE PROBLEMS

Most native plant communities furnish some grazing for livestock and wildlife There is great diversity in the nature of plant communities and in the degree to which overgrazing has influenced their present composition and density Basic to an understanding of the relations involved and to the adoption of improved land management procedure is a knowledge of the underlying biological sciences The principles of plant physiology and plant ecology apply directly to the improvement and maintenance of forage crops In this chapter we will consider pasture problems of a physiological nature

Plant Physiology in Range Research

Physiological studies of living organisms particularly emphasize the chemistry and physics of life processes Study of the physiology of plants differs from that of other organisms chiefly in the technique used Physiology is concerned with changes that occur in the organism and with the mechanisms involved Phases of morphological structure which are associated with and influenced by physiological processes will also be given consideration

Range vegetation is composed of a great variety of plants and researches have shown that some species endure grazing better than others The different reactions to grazing are accounted for by several factors chiefly by the location of the regenerative tissue that gives rise to new leafage and by the capacity of plants to set seed under grazing pressure

Generalized study of the responses of plants to their surroundings—the habitat—has contributed less to an understanding of their characteristics than would be expected Greatest advancement in our knowledge of plant adjustments to climate soil and biological factors—collectively termed environment—has come from study of the morphology and physiology of individual plant species Many such investigations may explain the presence dominance or absence of species in a given locality As an example characteristics such as size of plant

extent of root system, leaf area, and leaf structure are usually associated with density and hydration of the cell sap and with rate of transpiration. A knowledge of the physiological requirements that determine the presence or absence of a species in a habitat enhances its value as an indicator of the environment.

The application of the principles of plant physiology to range-land problems is in its infancy. This science should contribute much in the future; but this will be possible only if the range manager understands the many ways in which this science can assist him in solving his problems, and if the plant physiologist understands the problems confronting the range manager. Managers and technicians of range lands are primarily concerned with growing palatable stands of forage; they give little attention to the intricacies of growth of individual species. Physiologists, on the other hand, are not particularly interested in forage yield but are concerned with the mechanism of life processes of individual species as affected by the environmental factors. Both fields of work are useful; only a cooperative research work plan between them will make possible a sounder land-management plan.

The topics discussed in this chapter illustrate the usefulness of physiology in the field of range management and range-livestock production.

Roots and Root Systems as They Affect Range Problems

The growth habits of roots of the different plant groups are distinctive. Some plants have roots that endure trampling better than others (Fig. 11). Some roots are fibrous and many-branched, as in grasses and grasslike plants. If parts of these fibrous roots are pruned off by trampling animals, growth of the remaining portion will soon replace them. The roots of other plants are succulent, woody, of taproot form, or generalized with respect to branching, as in various forbs, shrubs, and trees. A few, like big sagebrush, have a two-storied root system (Fig. 11*F*, *G*, *H* and *I*).

The roots that give rise to the *primary root system* originate from the embryo and begin to develop when the seed germinates. Young plants are entirely dependent upon the primary roots for absorption of water. Contrary to some textbook statements, the primary root system of many cereal and range grasses remains active for several months (*31*). The later-appearing roots comprise the *secondary root system* (Fig. 11*B*).

Grasses and many other plants enlarge basally from shoots that originate from buds formed at or below the soil level. If the shoots grow up inside the sheaths of the parent stems, a bunchgrass, such as fescue, is formed. If the shoots push through the sheath and run along

the soil surface to form roots a mat is formed, as in Bermuda grass. If the shoots run underground to form rhizomes or rootstocks, a tough sod is produced as in Kentucky bluegrass. These modified stems, stolons and rootstocks, are jointed and bear scales which are actually reduced leaves. Roots develop from the lower side of the nodes and

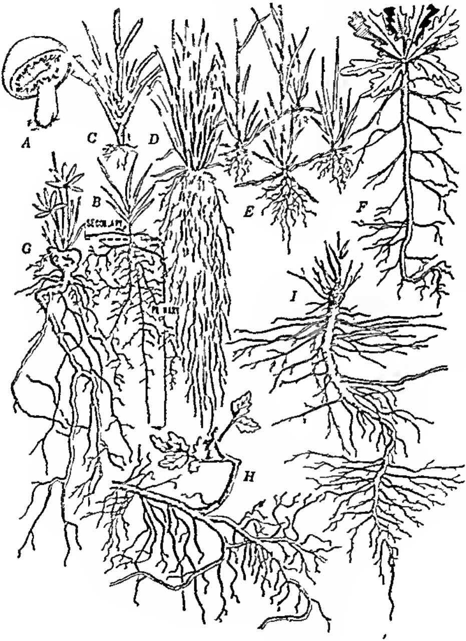

FIG. 11 Forms of roots and root systems of various native forage plants

leafy shoots from the upper side. These underground shoots give rise to new plants which also send out roots and rootstocks. In this way a dense network of rootstocks is formed, and new shoots or plants develop continually to replace the old ones (Fig. 11*E*). In bunchgrasses the tuft enlarges year by year as new shoots are produced from the lower nodes of each culm, two or more being sent forth each year (Fig. 11*D*). The dense tufts of Idaho fescue and similar grasses are composed of the young, leafy shoots which, the following year, are to bear the seed stalks. In densely tufted grasses only a few of these shoots actually flower (*21*). The life span of perennial grasses, although limited by heredity, is also influenced by the environment. Soils and favorable climate enhance longevity, whereas thin, dry soils and repeated close grazing shorten the life cycle by curtailing root and top growth. Plants of dry sites develop a widespread root system, whereas vegetation growing in moist, and especially in cold, soils forms a limited and shallow root system. Weaver and Clements (*30*) reported that roots of some native perennial grasses penetrated 6 to 12 feet deep in well-drained soils. Absorption of water and solutes is restricted primarily to the atea about 1 millimeter back of the root tip and to the thin-walled root-hairs which are located a short way back of the growing tips of the lateral branches. Accordingly, a large root system is advantageous. The extent of root development of plants subject to grazing is clearly reflected in the vigor of the aerial growth.

Morphology of Stems in Relation to Grazing

Stems of vertical growth habit form the central axis of the shoot. Aside from displaying branches, leaves, flowers, and fruit, the stem transports water and nutrients absorbed from the soil particles and acts as a food-storage organ.

Horizontal stems, at or below the soil line level, give rise to vegetative reproduction, as previously mentioned (Fig. 11*E*). In trees and shrubs the ascending stems are woody and perennial, whereas in grasses and forbs, which are herbaceous, the stems die back to the crown each year. Many semisucculent half-shrubs characteristic of dry sites have evergreen (chlorophyll-bearing) stems, and the leaves are sometimes reduced to mere scales—an apparent adaptation to aridity.

Although the selection of stems by grazing animals is not a physiological plant function, the degree of their utilization profoundly affects plant vigor, reproduction, and form of growth. Among other things, utilization of palatable stems depends on their growth habits, their content of the nonpalatable and only partly digestible cellulose and

lignin, their succulence and the presence of spines. Degree of utilization of palatable stems also depends on whether the branches are readily broken by bending. But regardless of how brittle the branches are, the taller species will remain vigorous because only a portion of the stems can be removed by browsing whereas young palatable reproduction or naturally low growing species may be destroyed by excessive cropping. The survivors tend to become "bushy" or otherwise distorted. Half shrubs like joint fur (*Ephedra* spp.) and highly palatable species like bitterbrush (*Purshia tridentata*) are often reduced to multi-stemmed, dwarfed plants as a result of too close browsing. Stems of plants like horse chestnut (*Aesculus californica*) and cliff rose (*Cowania stansburiana*) are so brittle that they are readily broken when bent by zealous browsing animals. Palatable succulent stemmed plants like cactus (*Opuntia* spp.) and heavily armed gooseberry (*Grossularia* spp.) are protected from overbrowsing by the presence of spines.

Physiology of Leaves and Maintenance of Forage Crop

Leaves are the primary organs in the economy of the plant and animal world because, in the presence of light, they convert carbon dioxide and water into stored energy. Through this process of photosynthesis green plants supply and maintain our energy, among other things it makes possible the maintenance of our herds and wildlife on the range. By seizing some of the solar energy, the green plant synthesizes a great variety of organic compounds and may, indeed, be regarded as the "chemist supreme" in the production of myriads of organic materials.

The all important leafy organs of most forbs, shrubs, and hardwood trees have two parts: the expanded *leaf blade*, and the slender stalk, or *petiole*. Leaves without a petiole like those of grasses and sedges, are said to be *sessile*. Internally the leaf is made up of thin, mesophyll cells containing abundant chlorophyll. The midrib and veins strengthen the leaf, they conduct the raw materials—minerals and water—to the leaf tissues and transport downward the excess substances formed in the chlorophyll.

The energy required by plants to carry out their life processes is obtained from the end products of photosynthesis—the carbohydrates and fats. When these compounds are transformed into carbon dioxide and water, the residual energy is liberated in respiration. Fatty substances and proteins are indirectly derived from the carbohydrates and are formed chiefly in the leaves. Proper range use depends largely on the amount of photosynthetic tissue (leafage) that has been produced in the spring when the grazing season opens and on the amount of the

Yet correlation with a number of environmental factors ly only suggest reasons for failure to survive Controlled ex- of specific environmental needs are desirable at each phase of It is known, for example, that plants require different tem for specific periods of their development, such as germination, rowth, and fruiting Also, there is no temperature *optimum* th as was formerly claimed, but rather an *optimal fluctuation* iture as the season advances

timate knowledge of physiological behavior and environmental mparable in detail to anatomical and morphological studies has attained for any important range plant, but there seems little hat such knowledge would aid in range management The use of plant hormones as weed killers illustrates the practical that may be achieved from studies of fundamental living es in plants

Seeds and Plant Propagation

nd only in importance to maintaining the plant cover in strong, logical vigor is the procuring of at least an occasional large, viable fruit crop To accomplish this, various physiological principles nge management techniques have been developed *(2, 4, 15, 19)* ny undertaking involving range revegetation, it is imperative to the germination percentage of the seed whether the seed will nate promptly under favorable growth conditions

first step in germination, the cells of the seed become saturated moisture and, with additional oxygen and carbon dioxide, the ing swelling ruptures most seed coats A second step after tion of the cells is growth in response to the activation of es such as diastase, which digest stored foods in the endosperm yledons, these stored foods being utilized in the growth of the o plant

ds of some species fail to germinate promptly when they are l in favorable environment The terms *dormancy* or *delayed nation* are applied to such "sleepy" seeds Dormancy is said to ought about because of one of the following causes *(10, 16)*

) *Water cannot penetrate seed coats*, as in hard coated seeds like bur clover lfalfa Scarification permits water to enter and to stimulate germination *ne seed coats are resistant to expansion of the embryo*, as with seeds of r l (*Brassica* spp) and pigweed (*Amaranthus* spp) Exposure of such seeds ezing and thawing softens the coat and favors germination (3) *Gaseous e may be retarded*, as with seeds of cocklebur (*Xanthium* spp) and many and composites Germination is slow because the tissues adjacent to the o inhibit ready intake of oxygen or possibly liberation of carbon dioxide

sequence of conditions such as cold temperature followed by warm, or the reverse. Germination may be delayed regardless of external conditions perhaps until weathering wears down a resistant coat or

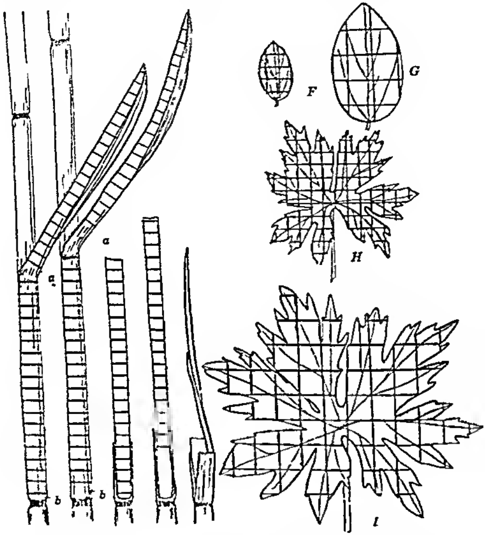

FIG. 12 Leaves of a grass, a forb, and a shrub marked to show areas of growth. Note localized growing region (*a, b*) at base of grass leaf blade and of sheath In broad-leaved plants growth is uniform throughout the leaf area.

leaches a chemical inhibitor. The prodigal waste between seed production and seedling establishment in even the most favorable environment is dramatically apparent.

By conducting a plant census of a given habitat, it should be possible to determine the phases of especial hardship through which all plants

must pass Yet correlation with a number of environmental factors can usually only suggest reasons for failure to survive Controlled experiments of specific environmental needs are desirable at each phase of plant life It is known, for example, that plants require different temperatures for specific periods of their development, such as germination, vegetal growth, and fruiting Also, there is no temperature *optimum* for growth, as was formerly claimed, but rather an *optimal fluctuation* in temperature as the season advances

An intimate knowledge of physiological behavior and environmental needs, comparable in detail to anatomical and morphological studies, has not been attained for any important range plant, but there seems little doubt that such knowledge would aid in range management The recent use of plant hormones as weed killers illustrates the practical results that may be achieved from studies of fundamental living processes in plants

Seeds and Plant Propagation

Second only in importance to maintaining the plant cover in strong, physiological vigor is the procuring of at least an occasional large, viable seed or fruit crop To accomplish this, various physiological principles and range management techniques have been developed (*2, 4, 15, 19*)

In any undertaking involving range revegetation, it is imperative to know the germination percentage of the seed whether the seed will germinate promptly under favorable growth conditions

As a first step in germination, the cells of the seed become saturated with moisture and, with additional oxygen and carbon dioxide, the resulting swelling ruptures most seed coats A second step after hydration of the cells is growth in response to the activation of enzymes, such as diastase, which digest stored foods in the endosperm or cotyledons, these stored foods being utilized in the growth of the embryo plant

Seeds of some species fail to germinate promptly when they are placed in favorable environment The terms *dormancy* or *delayed germination* are applied to such 'sleepy' seeds Dormancy is said to be brought about because of one of the following causes (*10, 16*)

(1) *Water cannot penetrate seed coats*, as in hard-coated seeds like bur clover and alfalfa Scarification permits water to enter and to stimulate germination (2) *Some seed coats are resistant to expansion of the embryo*, as with seeds of mustard (*Brassica* spp) and pigweed (*Amaranthus* spp) Exposure of such seeds to freezing and thawing softens the coat and favors germination (3) *Gaseous exchange may be retarded* as with seeds of cocklebur (*Xanthium* spp) and many grasses and composites Germination is slow because the tissues adjacent to the embryo inhibit ready intake of oxygen or possibly liberation of carbon dioxide

(4) *Embryos may be dormant* or seeds may have embryos not fully developed until well after the seeds have been cast Buttercups (*Ranunculus* spp) and holly (*Ilex* spp) are examples of this group In many seeds such after ripening periods take place during the winter Hence they can be planted in the previous fall, but in some seeds the after ripening period is much longer

The life span of seeds varies from a few months to many years (*16*) This fact apparently accounts for the sudden and often unexpected appearance, under highly favorable germination conditions, of dense invasions of species that perhaps occurred sparsely in former times For example, on burned chaparral areas which previously had long been protected from fire, thousands of brush and weed seedlings per acre come in where none was found before burning (*20*)

Effective range utilization presupposes that ample, viable seed will be produced to maintain the stand of choice forage plants As stated, this is possible only when the vegetation is kept in strong physiological vigor

Grazing in Relation to Organic Food Reserves

On any range area, removal of various amounts of growing herbage by grazing is taken for granted Sustained pasture yield, however, presupposes that enough leafage is left after each grazing season to favor storage of adequate food reserves for reproduction, overwintering, and vigorous spring growth The question is often raised as to whether close, repeated spring grazing is injurious if the range is cropped lightly in the autumn, or whether close midsummer and autumn grazing will injure the forage stand if spring grazing is light

To determine the reaction of perennial forage plants to utilization problems it is necessary to study the quantity of the organic food stored in stem bases and roots Most of the reserve substances stored in plants are composed of carbohydrates, fats and proteins Since the carbohydrates and fats provide the *main* source of energy for respiration and growth they are the storage substances quantitatively studied

As early as 1914 it was shown experimentally (*19*), and later by practical application, that deferred and rotation grazing were essential to maintenance of a good forage stand Sampson and Malmsten (*23*) assigned index values to represent plant vigor These values were based on calories of organic plant constituents contained in crowns and roots of clipped or grazed plants (Fig 13) For plants harvested (clipped) to 1 inch in height four times in a season for 3 consecutive years, the caloric index totaled a value of less than 100, for those clipped twice each year it was about 250, and for plants harvested only once yearly the value was more than 300 Later several investigators studied this

problem. On the western range, Sampson and McCarty (*22*) worked with purple or California needlegrass (*Stipa pulchra*), McCarty (*13, 14*) studied wild-rye (*Elymus ambiguus*) mountain muhly (*Muhlenbergia gracilis*), and wild oat (*Avena fatua*), McCarty and Price (*15*) used mountain brome (*Bromus carinatus*), slender wheatgrass (*Agropyron trachycaulum*), sticky geranium (*Geranium viscosissimum*), and niggerhead (*Rudbeckia occidentalis*), and Stoddart (*28*) studied bluebunch wheatgrass (*Agropyron spicatum*). In Wisconsin, Graber *et al.* (*8*) worked with alfalfa and other herbaceous

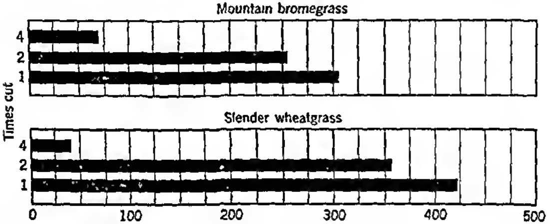

FIG. 13. Relative caloric indices of plant nutrients in crowns and roots of mountain brome (*Bromus marginatus*) and slender wheatgrass (*Agropyron trachycaulum*) when clipped once, twice, and four times respectively per season for 3 successive years. Clipping four times per season resulted in starvation and death of the plants, whereas clipping once or twice per season left the plants vigorous and productive.

perennials. In England and Wales Stapledon and associates (*26, 27*) conducted clipping experiments in connection with reserve food determinations. Weinmann (*32*) has reviewed the results of underground reserves of grasses and has studied food reserves of some South African grasses (*33*).

Reserve substances, also referred to as "food reserves" or "reserve foods," are organic materials produced by the plant and stored at certain seasons in the plant organs where they are utilized in respiration or at a later stage for growth. In grasses, reserves are stored mainly in the roots and rhizomes. The most important reserves are the carbohydrates, that is, starch and sugars, and the fats. The more complex polysaccharides, true cellulose, hemicelluloses, and pentosans, are essentially structural materials and are therefore not subject to nutritional plant support. The specific form, distribution, and relative proportions of individual reserve carbohydrates vary with the grass species (*1*).

Although the amount and the utilization of reserve substances in storage tissue of grasses and other herbs are influenced by environmental factors (*4*) workers seem to agree on most of the following points (1) Spring growth of perennial grasses is large or small according to the amount of food reserves stored in the basal organs during the preceding season (2) Food reserves in the underground storage tissues reach two seasonal low levels, the first shortly after the early spring growth has been produced, the second during the most rapid period of top growth in the summer (3) Storage declines more or less in proportion to the frequency and closeness of the grazing (or clipping) (4) Resistance of species to grazing is accounted for by large amounts of reserve substances stored in the underground plant organs, by season and closeness of grazing, and by growth characteristics such as prostrate form which prevents complete defoliation by grazing (5) Maintenance of a productive range depends on keeping the vegetation in a vigorous physiological state through the adoption of management plans involving moderate grazing intensity and, where practical, alternate seasonal grazing deferment. (6) Perennial grasses and forbs must have an ample supply of organic food reserves in late autumn to obtain the much desired strong spring growth (approximately 75 percent (*15*) of the total carbohydrates stored in autumn is consumed in producing 10 percent of the initial spring herbage growth) (7) Early, moderate spring grazing, and cropping again at herbage maturity in the autumn, neither materially depress accumulation of reserve substances nor weaken spring growth (8) Frequently, close grazing at immature stages results in thinning out palatable plants, because of storage of organic food reserves in stem bases and roots insufficient for respiration and spring growth (9) Winter injury, reduced root growth, and decreased drought resistance are associated with low concentrations of food reserves in the storage organs (10) Certain morphological differentiations that are inimical to translocation of food reserves appear to be correlated with excessive grazing and low carbohydrate levels (*18*) (11) The amount of reserve substances in underground parts of range plants is reflected in their vitality, longevity, herbage yield, root development, and seed production Close grazing throughout the growing season results in starving and thinning out of the more desirable species (2)

Figure 14 shows growth curves and total carbohydrates in underground organs of treated and untreated California needlegrass plants. The figure typifies for this region the seasonal pattern of reserve substances Minimum carbohydrate levels occur after inception of spring growth and again during the rapid summer growth period, for

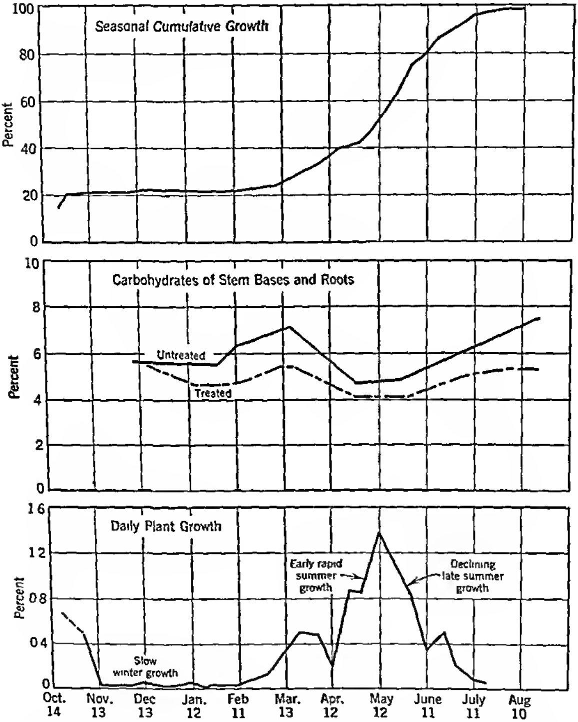

Fig. 14. Pattern of daily and of seasonal cumulative growth of undisturbed specimens of California needlegrass (*Stipa pulchra*), and of the total levels of carbohydrates in stem bases and roots of treated (clipped) and of untreated plants Note the relatively low percentage of carbohydrates in the spring (December to February) after growth has started, and the still lower levels of this constituent in the summer (April to May 15) when the growth is most rapid.

both treated and untreated plants This is followed by a sharp rise in reserve substances near the end of the season's growth activity

Seasonal Changes in Nutritional Values of Forage

An equally essential field from the viewpoint of the welfare of the animals grazed concerns the nutritional levels of the edible portions of the chief forage and browse plants

Although chemical analysis of herbage samples is not a specific measure of their digestible nutrients such data signify the approximate food value of a plant when considered in the light of digestion trials made with similar species Wholesome forage, high in crude protein and low in crude fiber, generally has desirable nutritive value On the other hand when growth is more advanced so that the crude fiber and lignin contents are high, digestible nutrients are low (*28*) Moreover, forage stands that decline to a low phosphorus content are likely to cause certain livestock deficiency diseases, indeed, abnormally low percentage values of any essential constituent in range forage can cause animal nutrition disturbances (*6, 17*) Malnutrition diseases such as brittle bone in grazing animals have been reported from many areas of the world The percentages of forage nutrients decrease with advancement in growth stages, and the lowest levels occur in standing forage that has been leached and bleached

Correct appraisal of the food value of forage species presupposes knowledge of their seasonal pattern of organic and mineral constituents Such patterns determine the need, if any, of supplementing the range forage with suitable concentrates (see Chapter 14)

Nutritive values of range forage plants vary widely, notably because of inherent dissimilarity in chemical levels of species, nature of the soil type, weather, and stage of maturity—stage of maturity having the most profound influence Hopper and Nesbitt (*11*) of the North Dakota Agricultural Experiment Station and Gordon and Sampson (7) of the California station concluded that the chemical values of a given species vary more during its entire growth cycle than the values of various species at any single growth stage

Lush (*12*) of the Louisiana station reported that the seasonal trend in pasture grasses is from high moisture and high crude protein in spring to low moisture and low crude protein by midsummer Stanley and Hodgson (*25*) found that range grasses in Arizona declined in protein carotene, calcium, and phosphorus from early growth to the winter period Fraps and Fudge (*5*) of the Texas station noted that protein and phosphorus were often deficient in winter Watkins (*29*) of the New Mexico station reported that the phosphorus require

ments for cattle were not met in the grasses analyzed after the peak of the growing season. Morrison (*17*) concluded that protein and other constituents of young grass are apparently always adequate for livestock.

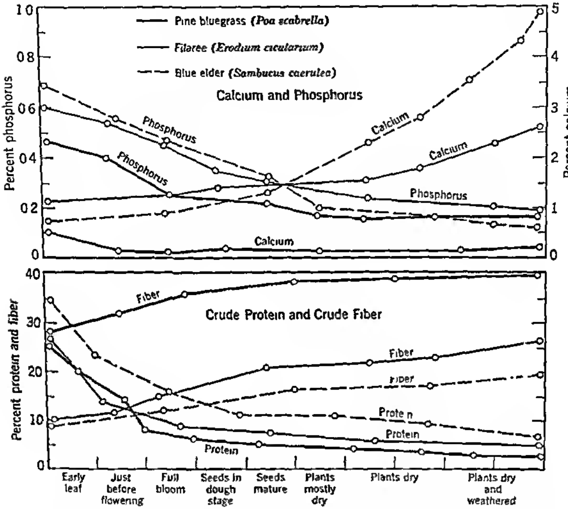

FIG. 15. Patterns showing percentage of crude protein, crude fiber, calcium, and phosphorus in a common grass, forb, and shrub at corresponding stages of development. Note the relatively narrow ratio of calcium to phosphorus in the grass at all growth stages and the widening of this ratio towards maturity in the filaree and the elder (7).

The composition pattern, as reported for pasture plants common to California foothill lands (7), will serve to illustrate typical nutritional characteristics of range-forage species (Fig. 15).

Closest correlation in composition in the cyclic march from spring growth to maturity was obtained by collecting samples in distinct growth stages rather than by chronological dates. These stages were: early leaf stage; just before flowering; full bloom; seeds in dough stage; seeds mature; plants mostly dry; plants dry or weathered.

In most grasses grasslike species and forbs there was a continuous and rather orderly decline in the percentages of crude protein, silica free ash phosphorus and potassium from the earliest appearance of leafage to plant maturity. The percentage of crude fiber in these plant groups, on the other hand increased with advancement in the season. The most rapid changes in constituents took place from early leaf development to the period of full bloom. In sharp contrast, the calcium levels in deciduous shrubs and most forbs either increased (or declined only slightly) with maturity but declined appreciably in grasses (Fig 15)

Both annual and perennial grasses were high in ash and crude protein from the early leaf stage up to full bloom. The grasslike swale plants (sedges and rushes), although not especially high in crude protein and mineral levels at any time, provided nutritious forage after the dry land grasses were mature and of low food value

Most forbs and shrubs of the California foothills, as in many other localities fall into two forage categories species such as bur-clover (*Medicago hispida*) and redstem filaree (*Erodium cicutarium*) which have a short vegetative period but maintain a high level of protein and ash content well into the late flowering stage, and species like whiteface lupine (*Lupinus albifrons*) and wedgeleaf ceanothus (*Ceanothus cuneatus*) which have a long vegetative period and are characterized by low levels of ash and protein when the flowering period is reached

From the viewpoint of chemical composition the following characteristics should typify the better herbaceous range plants (1) the interval between the beginning of growth and the flowering period should be long, (2) the crude protein content should remain at a relatively high level after the blossoming period and until the seeds attain the dough stage, (3) even after seed dissemination a portion of the basal leaves and stems should remain succulent, (4) in species whose basal herbage and stems mature early, a large proportion of the seeds should be retained after the aerial growth has become dry

As previously stated the calcium phosphorus ratio of range forage plants is also of significance in animal nutrition. It is not only important that the forage contain ample levels of calcium and phosphorus, but also the ratios of these minerals to one another should be fairly close, to favor satisfactory assimilation (3). In some range species the percentage of calcium changes little from early growth to maturity, whereas the levels of phosphorus decline consistently, thereby causing disproportionate ratios and poor assimilation of both these minerals in the later plant stages. An ideal ratio of calcium to phosphorus is 1 1,

but Morrison (*17*) reports no ill effects from a ratio as wide as 6 5 1 An ample supply of vitamin D appears partly to nullify the otherwise ill effects of moderately wide ratios of these minerals in the forage

Grasses tend to have a much closer ratio of calcium to phosphorus than other plant groups In all grasses studied in California the calcium-phosphorus ratio is near 1 1 at all growth stages (7) In many forbs and shrubs, on the other hand, the ratio of mature leafage is surprisingly wide For example, in mature leafage of redstem filaree (*Erodium cicutarium*), tomcat clover (*Trifolium tridentatum*), and fineleaf lotus (*Lotus subpinnatus*) the higher ratios recorded were 13 0 1, 24 7 1, and 27 9 1, respectively, and in mature leaves of such common shrubs as California buckeye (*Aesculus californica*), blue elderberry (*Sambucus caerulea*), and blue oak (*Quercus douglasii*) the higher ratios noted were 23 9 1, 50 7 1, and 15 4 1, respectively The choicest forage after plant maturity consists not only of those species with a desirable calcium phosphorus ratio but also those having moderately high levels of crude protein, vitamin A, and total digestible nutrients

The Role of Hormones and Vitamins

Among the chemical factors that affect both animals and plants, the hormones and vitamins deserve consideration Both are chemical substances required in micro quantities by the animal body The distinction between these two types of substances from a metabolic viewpoint is somewhat arbitrary The term hormone is applied to chemical substances produced in one part of the animal organism, usually in special glands and utilized in micro quantities by tissues located elsewhere *Examples are thyroxine, epinephrin, and insulin* Vitamins are chemical substances also used in micro quantities, but not all are produced in the animal body Examples are vitamins A, C, D, and the quite different compounds making up the B complex

Physiological Reaction of Hormones

The plant hormone auxin (indoleacetic acid) is the only one conclusively demonstrated to influence activities of plants It is produced in root and shoot apices, from which it diffuses, and is associated with such phenomena as tropisms, bud inhibition, root production, and tillering Vitamins also are produced by the plant and enter into essentially the same physiological reactions within the plant as they do within the animal Accordingly "growth substances' is a better term to use when discussing hormone vitamin and other such little known substances in relation to their influence on plants

Vitamin A	Vitamin D
Vitamin B complex	Viosterol
Nicotinic acid	Calciferol
Pantothenic acid	
Riboflavin	Vitamin E
Thiamin chloride	Tocopherol
Others	Others
Vitamin C (ascorbic acid)	Vitamin K

Vitamin A or Anti Infective Factor This fat-soluble vitamin is ingested by the animal in the form of a precursor, *carotene*, which is found abundantly in growing plants and in green cured hay Animals subsisting on a diet deficient in vitamin A are usually more susceptible to specific infections, especially of the epithelium or of the mucous membranes of the respiratory tract, than those receiving ample amount of this vitamin Vitamin A in combination with certain other vitamins and co enzymes is necessary for normal development and reproduction of animals Herbivores obtain a rich supply of vitamin A from green pasture, whereas man gets this factor from foods of animal origin—milk fat, egg yolk, liver, fish-liver oil—and also from green and yellow vegetables

Although greenness of hay indicates the presence of carotene, the loss of this substance from plants is much more rapid than is the loss of the green color, hence carotene content cannot always be judged by appearance alone (*3*, *9*) Ripening or mature pasturage or bleached (nongreen) hay contains little carotene (*24*) Since vitamin A is stored in the liver of most animals from food rich in carotene, the health of these animals is protected for various periods when they are subsisting on a diet low in this precursor

Vitamin B Complex or Anti-Neuritic Factor More than half a century ago, when polished rice provided the main food of man in oriental countries, beri beri a disease that causes loss of appetite and degeneration of the gastro intestinal tract, was widespread The discovery, beginning in 1897, of prevention or cure of the disease by feeding the whole (unpolished) rice grain, or extract from rice millings provoked much study It is now known that the vitamins of this complex have many diverse functions, not only do they affect the gastro intestinal system but also the nervous system, and they are apparently essential to the health of all living cells Such complexes as thiamin chloride, riboflavin, and nicotinic acid function to complete the structures of certain enzymes that are part of enzyme systems necessary for oxidation and assimilation of carbohydrates Cattle and some other ruminants evidently need not ingest B complex vitamins, since

these are apparently synthesized by certain bacteria in the digestive tracts of these animals Man finds rich sources in milk, whey, liver, kidney, meat, and yeast

Vitamin C or Anti-Scorbutic Dietary Factor Although this vitamin is apparently not necessary for livestock, scurvy is a serious disease of some animals whose intake of vitamin C is low Scurvy is associated with brittleness of bones, swollen joints, inflammation of gums, loosening of teeth, and sensitiveness Man, monkey, and guinea pigs store vitamin C for short periods in the adrenal cortex, but such reserve is soon depleted when these animals subsist on a diet lacking in vitamin C Apparently, not all animals are subject to scurvy Calves have been raised successfully without the anti scorbutic factor Cattle, hogs, and poultry either synthesize vitamin C in the digestive tract or have a low requirement for this factor Of the animals studied, only man, other primates and the guinea pig apparently have no capacity to synthesize this vitamin Man obtains his requirement chiefly from fresh fruits, especially citrus and from berries green vegetables, and limitedly from milk

Vitamin D or Anti-Rachitic Factor Functioning in the normal calcification and phosphorylation of bone in young animals, vitamin D must be abundantly available during pregnancy, lactation, and growth Vitamin D is supplied by the consumption of suitable foods, by ingestion of matter secreted from the glands, as in grooming the body by licking and preening, and by absorption of the products of insolation formed on or in the skin through a precursor, *ergosterol* Livestock get most of their needed supply of this factor from exposure to sunlight Fresh green pasture grass contains little or no vitamin D, and sun cured hays and fodders contain only a small amount The name 'anti rachitic refers to the property of this vitamin to prevent rickets when the diet contains adequate calcium and phosphorus in desirable proportion Human beings obtain concentrated supplies from fish liver oils butter, egg yolk, and milk

Vitamin E or Anti Sterility Factor This vitamin, like vitamin A, is needed for normal reproduction of many animals, including man, chickens, and rats Experimental evidence of the requirement of vitamin E in the feed of cattle has not been fully confirmed In the rat, lack of vitamin E causes death and reabsorption of the fetus failure of pregnancy, sterility in males In addition to the function of this vitamin in the promotion of growth, it also influences muscular control and the health of nerve cells Injury to specific tissues caused by the lack of vitamin E entails irreparable damage Seeds nuts, green herbage, and fresh vegetables are rich in vitamin E

Vitamin K This little known, fat soluble vitamin factor functions in the clotting of blood, it is essential to chicks and presumably to other animals This vitamin is found in fractions of various unsaponifiable animal and plant fats, alfalfa providing a rich supply Ordinary poultry rations and pasture forage seem to contain enough vitamin K to satisfy requirements Both this factor and certain synthetic substances are used in medical clinics for protection from severe hemorrhages

Other Vitamins Several other factors necessary for normal growth and development of animals have been investigated, but knowledge concerning them and their relation to livestock is even less understood than those discussed

Application of Vitamin Studies to Range Management

Since the vitamin B complex and vitamin C are evidently synthesized in the digestive tract of grazing animals they are of no concern where there is ample, nutritious range forage Likewise, vitamins D and E are seldom if ever deficient in the bodies of range livestock In the far north, however, insufficient ultraviolet light in winter could fail to react sufficiently on the precursor *ergosterol* in the skin to form adequate amounts of vitamin D On the other hand, vitamin A, which is sensitive to heat and light is likely to become deficient where stock are pastured for long dry periods on dry bleached pasturage The symptoms most commonly observed in cattle are birth of dead or weak calves, commonly associated with retained placenta, severe diarrhea in newborn weak calves, and eye lesions particularly in immature animals, causing night blindness or inability to see in dim light Deficiency of this vitamin may be remedied by supplementing the animal s ration with yellow corn or with green, well cured alfalfa hay (*3*) Better still, the animals should be placed on fresh green pasture Palatable evergreen browse is also helpful When vitamin A deficiency is suspected, a sample of the liver or blood of a suspected animal should be sent to a reliable laboratory for analysis

Certainly the vitamin requirements of pasture animals and other farm stock is a promising field of further nutritional research

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Chapter 4

PLANT ECOLOGY AS APPLIED TO RANGE PROBLEMS

In the preceding chapter it was pointed out that many range problems can be solved by physiological plant studies However, since every environment has many diverse facets, it must be investigated from many angles involving various field measurements These studies—which are outside the sphere of the physiologist—call for the ecologist who is trained in vegetal techniques and is qualified to synthesize the researches of related studies

Plant Ecology in Range Research

Although various practical ecological field measurements were employed early in our civilization, it was probably not until in the 1880's that the German botanist, Hackel, presented the word *ecology* to the scientific public The term is derived from the Greek word *oikos*, meaning home, and *logos*, study Definitions of ecology have been in keeping with the original etymology

Ecology may be broadly defined as a study of reciprocal relations between organisms and the environment More specifically, ecology is that branch of biology that endeavors to explain the origin, variation, and function of plant and animal structures and the nature of vegetal and animal communities Plant ecology, as is implied, emphasizes the study of plants and their environment, animal ecology involves the study of animal organisms in relation to their habitat

Although ecology, *per se*, implies consideration of the interaction of all the organisms in a given habitat, Clements and Shelford (*6*) attempted to clarify these relations by proposing the term *bioecology* This term covers the coaction of the habitat and the biota as a whole including both animals and plants The vegetation exerts the dominant influence on the environment, however, damage to the vegetation may temporarily cause animals to exert the greater influence on the habitat As an example, on overgrazed range lands the characteristic increase in

rodents may result in marked change in the soil and in the developmental trend in the vegetation.

Field study of ecology has a twofold approach. The first considers the ecology of the individual organism in relation to its environment and is termed *autecology*, or the ecology of the individual. This may include consideration of genetic history, morphology, and reproduction of one or more species in relation to the environment. The other objective considers the vegetation as a whole in relation to climate, soil, and the biotic factors. Study of this nature is termed *synecology*, physiographic ecology, or merely the ecology of vegetation. These two study aspects—autecology and synecology—cannot be kept entirely separate if complete information on a plant cover is to be obtained (*23*, 27). Both provide a source of useful information on the conservation of our natural, renewable resources.

The Plant Community

On any natural land area, different plant species are grouped together on sites congenial to their life-history requirements. These patterns of vegetation, some large, others small, constitute the so-called plant communities or social units. If the community becomes the center of research interest, it must be considered in all its details: its extent, the period of its development, the quality of its structure, and its relation to climate, soil, and all biological influences (*33*).

Within a large forest or grassland area many plant communities may occur. In rugged terrain, for example, three communities might be found: a grassy meadow, a coniferous forest, and open woodland or grassland. Each of these communities is clearly distinguishable by species and aspect. The term community does not distinguish between successional rank of the vegetal units, and the different plant communities are designated best by the dominant species of their cover.

Although the subject of ecology is admittedly overburdened with terminology, the following terms pertaining to classification of the community are defined here because of their usefulness in studying range vegetation.

Colony. A plant community of two or more species, which is young in development and is therefore subject to replacement by more permanent vegetation. *Society*[1]. A relatively stable community dominated locally by one or more species that are merely subdominant within a larger vegetal unit. Both *aspect* and *layer societies* are recognized. Aspect societies are especially discernible during the main blossoming period or while in gay foliar coloration. Layer societies are recognized by the presence of low stature plants such as

[1] This definition is in contrast to the term "societies" in animals which implies mutual attraction of individuals through characteristics of the nervous system.

grasses which form a distinct vegetal level under tall forest or brush *Association* The grouping together of two or more homogeneous societies of similar life form within a climatic unit recognized by the dominance of two or more species *Consociation* Communities where 70 percent or more of the plant cover is composed of a single climax species such as buffalo grass in the short-grass plains or a pure stand of ponderosa pine in a coniferous forest *Plant formation* The most extensive climax of a common life form within a region of similar climate, including two to several closely related associations, such as all the grassland associations or all associations of hardwood forests Recognition of the formation is especially useful in geographical studies

Life Forms

In any detailed study of vegetation, the initial step is to classify the cover into dominant life forms such as grass, forbs, shrubs, and trees This classification reflects the character of the environment and often indicates the best uses of the land A more refined classification of life forms, especially popular among European ecologists, was proposed by Raunkiaer (26), who recognizes five divisions based on their adaptations to endure the unfavorable season (Fig 16)

1 *Therophytes* Annual grasses and forbs that pass through the unfavorable season in the seed stage and complete their life cycle (from seed to seed) in one growing season

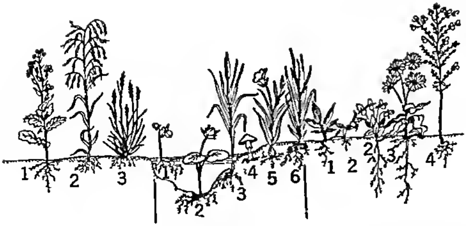
2 *Cryptophytes* Plants whose buds or shoot apices survive the unfavorable season in the ground, or at the ground level if they are growing in water Cryptophytes are divided into three groups *geophytes*, including all land plants with subterranean buds—bulbs stem tubers, root tubers, and rhizomes, *helophytes*, marshland species whose surviving buds are in water or mud but whose top growth is above the water level, and *hydrophytes*, water plants whose reproductive buds lie at the bottom of the water—not necessarily embedded in the mud—and whose vegetative shoots are submerged in water so that only the flowers rise above the water level

3 *Hemicryptophytes* Perennial bunchgrasses and similar plants whose shoots die back to the ground surface at the beginning of the unfavorable season leaving the reproductive buds protected by the upper soil layer and the remains of the weathered plants

4 *Chamaephytes* Sodgrasses and grasslike plants with buds situated on decumbent shoots, or stolons, which lie on or very near the surface of the ground In cold regions the buds are protected by snow, in hot, dry areas by the remains of the withered plants

5 *Phanerophytes* Trees, shrubs, woody lianas, and stem succulents with buds not conspicuously protected, which extend into the air on stems that persist for several years

A broad census of the dominant life forms in a plant association or a formation may be made by sampling various communities (34) A letter or a combination of letters is used to designate each life form (Th) therophytes (Cr) cryptophytes, (H) hemicryptophytes, (Ch) chamaephytes, and (Ph) phanerophytes The summarized data, the "biological spectrum" of the formation, show the distribution of the life forms and indicate the character of the climate



THEROPHYTES

Common mustard (*Brassica*)
2 Wild oat (*Avena*)
3 Annual fescue (*Festuca*)
Russian thistle (*Salsola*)
Tumbleweed (*Amaranthus*)
Vetch (*Vicia*)
Filaree (*Erodium*)

CRYPTOPHYTES

HYDROPHYTES
1 Pondweed (*Potomageton*)
2 Pond lily (*Nymphaea*)

HELOPHYTES
3 Cat tail (*Typha*)
Rush (*Juncus*)

GEOPHYTES
4 Common mushroom (*Agaricus*)
5 Lily (*Calochortus*)
6 Iris (*Iris*)

HEMICRYPTOPHYTES

1 Strawberry (*Fragaria*)
2 Violet (*Viola*)
3 Balsam root (*Balsamorrhiza*)
4 St Johnswort (*Hypericum*)
Yarrow (*Achillea*)
Sedge (*Carex*)
Larkspur (*Delphinium*)

CHAMAEPHYTES

1 Twin flower (*Linnaea*)
2 Bermuda grass (*Cynodon*)
3 Sandberry (*Arctostaphylos uva ursi*)
Stone crop (*Sedum*)
Bell flower (*Campanula*)
Mat hawksbeard (*Crepis*)
Beardgrass (*Andropogon*)

PHANEROPHYTES

1 Barrel cactus (*Echinocactus*)
2 Sagebrush (*Artemisia*)
3 Chamise (*Adenostoma*)
Prickly pear (*Opuntia*)
Manzanita (*Arctostaphylos*)
Whitethorn (*Ceanothus*)
Spurge (*Euphorbia*)
Rabbitbrush (*Chrysothamnus*)

4 Giant cactus (*Cereus*)
5 Redwood (*Sequoia*)
6 Oak (*Quercus*)
7 Grape (*Vitis*)
Willow (*Salix*)
Pine (*Pinus*)
Madrone (*Arbutus*)

FIG 16 Illustrated lists of Raunkiaer's major plant classes, based upon their adaptations to endure the unfavorable season (26).

marked, because severe competition makes replacements in the plant cover slow and inconspicuous. Sometimes, notably under grazing use or by fire, a *subclimax* or subfinal stage of plant development may exist for a long period.

On only slightly disturbed areas the native vegetation ultimately remains reasonably stable. The entire cover is composed of the species that could best endure the existing conditions of soil, climate, and plant and animal competition. Even on bare areas there is a continuous struggle among plants for a foothold and nutrients. The struggle goes on in every place that can support plant life, from bare rocks, seashore, or swamp, to rich forest lands. Those plants will survive that can best endure adverse conditions or that thrive best under favorable ones. Whereas plants are governed by their environment, they in turn work changes in it. These changes, slight as they may be in any one season, react upon the plants, which must adjust to the changes or give way to other species better fitted to the altered conditions (*13*, *29*, *33*, *40*, *41*).

Stages of Succession

The normal vegetal development from bare rock with a sparse lichen cover to a well-developed soil supporting perennial vegetation usually passes through five fairly well-defined stages (Figs. 17 and 18).

Initial or Pioneer Stage

Initial development begins on bare rock where windborne sporidia of lichens adhere, germinate, and form small, grayish-green patches of growth (Figs. 17*A* and 18*A*). The lichens corrode the surface of the rock, and grains of dust and spores of mosses catch in the uneven surface of the lichen or around its edges. As the moss develops and catches more dust and holds water from rain and snow, the rocks are cracked, slowly disintegrated, and partly dissolved. Thus nutrients are made available for higher plant life, and more soil is formed and held.

Transition Stage

Some seeds of shallow-rooted annual flowering plants gain a foothold on the scant soil developed by the pioneer invaders. The plants of the initial stage give way as these annuals increase and form the *transition* stage (Figs. 17*B* and 18*B*).

First Herb Stage

At the advent of the first herb stage the soil is coarse and has low water-holding capacity and limited organic matter; hence the invading

plants are shallow rooted and early maturing This cover indicates conspicuously low forage value (Figs 17C and 18C)

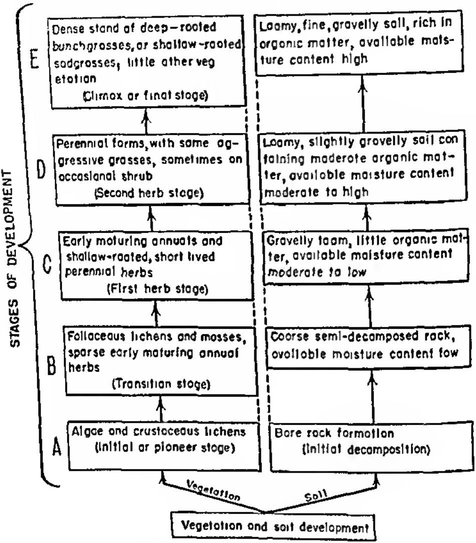


Fig 17 Typical stages in plant and soil development from the initial succession on bare rock to a perennial cover on well developed soil where grass constitutes the climax

Second Herb Stage

With continued formation of soil and humus, the plants of the first herb stage are replaced by perennial broad-leaved herbs and a few short-lived perennial grasses, that is, by *second-herb-stage* plants (Figs 17D and E and 18D) Usually this stage is invaded by plants of various life forms and eventually passes into a mixed grass-and-forb cover

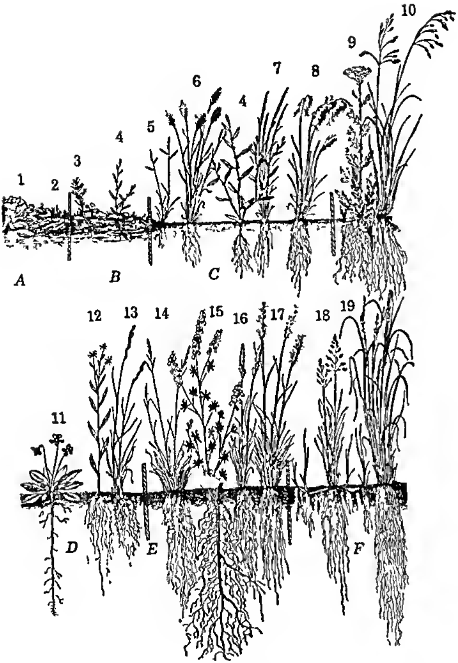


Fig. 18. Trends of plant invasions on range lands where grass constitutes the climax vegetation. *A*, Pioneer or initial stage. *B*, Transition stage. *C*, First herb stage. *D*, Second herb stage. *E*, Mixed grass and herb stage. *F*, Climax stage of deep-rooted perennial grasses. 1. Lichen. 2. Moss. 3. Tarweed. 4. Knotweed. 5. Annual fescue. 6. Red brome. 7. Fescue. 8. Downy chess 9. Yarrow. 10. California brome. 11. Tongue-leaved violet. 12. Aster. 13. Showy melicgrass. 14. Idaho fescue. 15. Lupine. 16. Junegrass. 17. Small needlegrass. 18. Kentucky bluegrass. 19. Smooth wild-rye. Intermediate elevation, California.

Successional Behavior on Denuded Range Areas

Areas that formerly supported a perennial grass cover but were denuded by overgrazing or plowed and abandoned typically pass through four to six successional stages before reaching climax These stages are comparable to those described above.

A good example of successional behavior of denuded grassland is illustrated by Shantz (*31*), who studied the revegetation of abandoned roads on short-grass range in eastern Colorado Under conservative range use the natural vegetation consisted largely of blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*) The grama-buffalo grass association predominates throughout the central portion of the Great Plains region If it is plowed and abandoned after having been cultivated for some years, the native grama-buffalo grass sod will regain dominance in from 25 to 50 years A similar period is required to revegetate areas denuded by overgrazing The following successional stages typically occur

(1) An early herb stage of rather scattered annual plants largely forbs (2) A heterogeneous late herb stage of annual and short-lived perennial forbs of such density as to utilize the water available for growth (3) A short-lived stage of squirreltop (*Sitanion* spp) and similar growth forms (4) A perennial stage of fairly tall bunchgrasses (5) An early short-grass stage of buffalo grass and muhly (*Muhlenbergia* spp) (6) A late or climax short-grass stage of blue grama buffalo grass leading to formation of a sod

On these denuded lands the soil is well supplied with water, and *conditions are favorable for seed germination and plant growth* The successional pattern is largely determined by the amount of seed that enters the denuded area, germinates, and becomes established Since blue grama reseeds slowly, it is the last to become reestablished As the climax sod cover gains dominance, the nonsodforming species disappear because of competition

Other Successional Grassland Trends

The successional sequences outlined above may seem somewhat theoretical, but the trends indicated are repeated time and again, with some variation under different intensities of grazing and climatic variations Fire, overgrazing, and/or protracted droughts may cause the climax vegetation to give way for a time to plants of lower successional stages

An illustration of successional trends up or down the scale of development according to the degree of pasture use is shown for two different climatic regions in California The column to the left depicts suc-

cessional trends in the annual grass and cover of the foothills, and the column to the right shows similar trends in the perennial grass association of the mountains

Declining Range	Annual Range	Improving Range	Perennial Range	Declining Range
	A High Annual Stage (Light to moderate grazing) Wild oats (*Avena* spp) Soft chess (*Bromus mollis*) Ripgut (*Bromus rigidus*) Bur-clover (*Medicago hispida*)		*A Climax Stage* (Light to moderate grazing) Wheatgrasses (*Agropyron* spp) Bluegrasses (*Poa* spp) Needlegrasses (*Stipa* spp) Redtops (*Agrostis* spp)	
	B Intermediate Annual Stage (Moderate to heavy grazing) Foxtail fescue (*Festuca megalura*) Filaree (*Erodium* spp) Red brome (*Bromus rubens*)		*B Subclimax Stage* (Moderate to heavy grazing) Perennial fescues (*Festuca* spp) Junegrass (*Koeleria cristata*) Spike trisetum (*Trisetum spicatum*) California brome (*Bromus carinatus*)	
	C Low Annual Stage (Heavy to destructive grazing) Tarweed (*Hemizonia* spp) Silver hairgrass (*Aira caryophyllea*) Turkey mullein (*Eremocarpus setigerus*)		*C Low Transition Stage* (Heavy to destructive grazing) Aster (*Aster* spp) Pentstemons (*Pentstemon* spp) Sagebrush (*Artemisia* spp)	

The range supporting annual vegetation lies in a dry, mild climate of the foothill region whereas the range dominated by perennial bunch grasses occurs in a relatively moist, cool climate of the mountains Although the species representing the different successional trends vary according to locality, they are generally of similar growth form

The climax cover is not always the most useful to man and his animals, hence the lands may be purposefully managed so as to favor a moderate disclimax which however, should never be permitted to decline too far down the successional scale Wild oat, soft chess, and bur-clover are upper scale plants abundant on well managed annual range lands of

the foothills. In contrast, tufted hairgrass, bluegrasses, needlegrasses, and fescues abound on conservatively grazed California mountain ranges. Too commonly, excessive grazing has thrown the cover back to so early a successional stage that revegetation requires many years of skillful management.

Range Indicators

All species—indeed all plant communities—portray the conditions of their environments. This fact is expressed in the term "plant indicators" or "range indicators" when applied to grazing lands (Chapter 16).

Although plants have been used since ancient times to depict the characteristics of habitats *(30, 32, 36)*, the indicator concept on range lands in North America was not widely used until the turn of the century. At present, indicator plants are fairly well understood and extensively employed in the management of range areas. For example, excessive grazing soon provides "clues of happenings" by showing changes in the plant population. According to Talbot *(36)*, any plant or soil condition that shows historic change in composition or density is a useful indicator. This viewpoint is supported by McGinnies and associates *(21)* who concluded that:

> To the experienced observer, plants either as individual species or as communities may indicate soil type and productivity, climatic conditions, and status of the plant community from the viewpoint of the land administrator.

The above viewpoints have been corroborated and expanded by Sampson *(30)* as follows:

> The plant indicator concept is based on a cause-effect relationship where the effect is taken as a sign of the cause. All plants are admittedly a measure of their environment. Because plant production, and to some extent form of growth, is determined by the habitat, any plant species may, to some extent, indicate the nature of its surroundings; yet only a few key species of a given locality are, as a rule, sufficiently restricted by growth conditions to be helpful.

In line with these philosophies, Shantz *(32)* noted that the plant cover serves as an indicator of the climate "under which it is produced, of the soils on which it has been produced, and of the practices of grazing or other use to which it has been subjected."

Practically all investigators agree that a close relationship exists between the indicator significance of the community and the species that compose the cover. According to Clements *(5)*, both the com-

species on a chart or map Generally, though there are exceptions, the basal or crown area is traced out rather than the foliar or aerial growth Stem counts are commonly made at or near the end of the grazing season, to indicate the degree of cropping and the seedling reproduction that may be expected The facts noted will usually show whether a specific grazing practice is in harmony with the growth requirements and maintenance of the vegetation However, the cost and accuracy of the facts recorded are to a large extent dependent on the kind of plots used and the nature of the study

The more popular and useful plots are listed and described herewith

Quadrats and Similar Vegetal Plots	*Transects*	*Animal Control Plots*
Chart quadrat	Strip transect	Enclosure
Basal area plot	Line transect	Exclosure
Clip plot	Point observation transect	Seasonally protected enclosure
Denuded plot		
Census plot	Bisect	Hurdle plot

Quadrats and Similar Plots

Originally a square area of 1 meter the term quadrat is now applied to relatively small, square plots of different sizes, which are delimited on all sides

Quadrats may be temporary or permanent Temporary quadrats are used to study the character of existing vegetation, they are abandoned after the data have been recorded Permanent quadrats are used to study changes in vegetation as a function of time and treatment and may be reexamined periodically for many years

Chart Quadrat The chart quadrat is employed for making a detailed graphic record of plant composition on the plot The mapping is often done to a scale of 1 10 on coordinate paper with divisions 1 square centimeter in size The chart quadrat method is tedious and expensive and useful only where much detail is needed

The movable strap method of quadrat charting uses leather or metal straps to delineate the plot The straps are marked off at each tenth interval each mark being the base for the location of two other straps which are laid across the quadrat and moved from one unit or strip to another as charting proceeds With the boundary straps on the ground as a reference grid the plant composition of the entire plot is charted (*23*, *28*, *41*)

The field pantograph designed by Hill (*16*) to expedite positional plant charting accurately traces the boundaries of mats and tufts of

vegetation and locates individual species where the vegetation is not overly dense. The instrument consists of a low stand to support the map, the pantograph arms, and a "pointer" for tracing tufts or locating individual specimens (Fig. 19). Two men operate the pantograph but only one need have knowledge of the vegetation. One operator records the symbols of the species whose positions are automatically

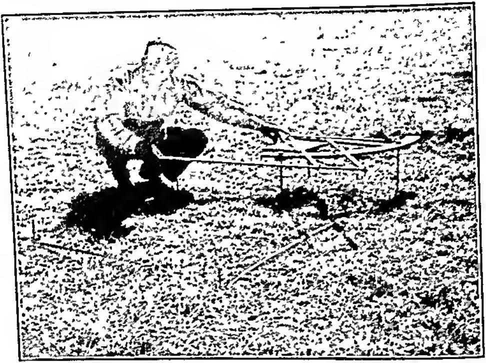


FIG. 19. Charting vegetation through the use of a pantograph. One of the operators is absent taking the photograph.

located on the map. The second operator guides the pointer to individual specimens or traces the boundary of tufts or mats of vegetation. These basal areas are reduced to scale, usually to one-fifth. The instrument can be used on any topography. In 1949, cost of constructing a substantial Hill-designed pantograph was about $40.

Basal-Area Plot. This kind of plot is of advantage on bunchgrass range where a pantograph is not available for obtaining basal area of each tuft-forming grass. The plots may be of any convenient shape of known size but usually cover 1 square meter. The area of each grass bunch is measured and recorded by species. A scale, which is graduated in units of area, may be used to measure bunch diameters. Seedlings, single-stemmed annual grasses, and forbs may be listed by numbers of specimens present, or their basal area may be estimated.

Basal-area plots yield the following information: density, species composition, number of plants and basal area of each plant.

"Clip" Plot. The clip plot is used mostly to determine the weight (yield) of forage produced under different intensities of grazing or clipping or to measure potential forage yield on different sites. Plots located at random are clipped at a predetermined height, and the harvest is segregated either into individual species or grouped into grasses, forbs, and shrubs. The weight of each segregate is recorded air or oven dry. To expedite study of this nature, Pechanec and Pickford (*25*) merely estimated the green or dry weight of the plant cover, by species, on replicated plots. After actually weighing the plants of a number of plots, close estimates of weight could be made.

Denuded Plot. When all growth is removed, as by burning, excessive grazing, or digging out of the vegetation on a permanently established plot, the unit is called a *denuded plot*. In partially denuded quadrats, all but the species of special interest are removed. Plots of this kind are useful in studying trends in succession. They are also useful in determining viability of seed and survival of seedlings, since they simulate natural conditions.

Census Plot. The census plot is most commonly employed to obtain quantitative data on how frequently species of special interest occur in relation to the total plant population. Three kinds of census plots are used, depending on the specific objective, namely, the list quadrat, the stocked quadrat, and the frequency index quadrat.

The list quadrat is useful in census studies, since it is expedient and relatively efficient. The presence of each plant species on a plot is noted, but its total number in the stand need not be counted unless the study is concerned with the abundance of individual species relative to time. The data are usually recorded on each of the 10 plot strips of a regular quadrat map form. Where more detailed data are desired, the chart and list methods of mapping, as proposed by Malmsten (*22*), may be used. After the plot has been subdivided into convenient units for mapping, the vegetal density is estimated to the nearest tenth. The plant species are recorded in order of their abundance and percentage of area each one occupies, and the boundaries of important tufted plants are accurately charted. This system reduces charting time and assembles the data in convenient form for computation.

The stocked quadrat is an adaptation of the listing technique in which plant species, by plot, are expressed in qualitative terms (*24*). For example, in determining the success of seedling establishment in a reseeding study, 10 seedlings per square meter may be classified as good stocking, 5 as fair, and a fewer number as poor. By this method

the different portions of the range area can be segregated into go
fair, and poorly *stocked units*

The frequency-index quadrat merely notes the number of spec
present on a series of plots The percentage of the total number
plots containing the species of interest, that is, their frequency p
centage is computed and summarized by classes If distribution
species is 'normal," a reversed J-shaped curve results (Fig 20),
dicating the presence of relatively abundant sporadic species, fev
intermediate plants, and larger numbers of dominants Stable pl
associations tend to produce the "normal" J-shaped frequency inc
curve, whereas disturbed associations bring about curves of differ
shapes

Frequency-index plots determine the effect of various systems
grazing use on plant communities, as demonstrated by Hanson and E
in Colorado (*15*) One pasture was grazed continuously each y
throughout the summer and fall, a second was subjected to deferred a
rotation grazing Half of the second pasture was deferred from gr
ing until after seed maturity, the other half was grazed before t
seed crop ripened Grazing deferment was alternated between hal
of the pasture on a 2-year rotation The frequency index curves
the two pastures are distinctly different (Fig 20), because of t
decline of some of the highly palatable dominant species resistant
continuous grazing

The frequency index analysis provides a rapid method of dete
mining species abundance in an association but must be used wi
caution, since the index tends to vary with size of plot in relation
density of vegetation (*12*)

In general, frequency-index plots should be 0 1 to 1 square met
in size, depending upon the density of the vegetation, or large enou
to include several species in the 80 percent frequency class Frequenc
index curves for different uses are not necessarily commensurable f
comparison unless plots of the same size are used throughout

Transects

Plots under this category may consist merely of a line or of a series
squares or rectangles lying end to end The latter may vary in wid
from a few inches to several feet, hence their length is several tim
their width Transects may be located at random or laid out m
chanically with respect to area or environment They are especial
useful in noting the degree of variation in species frequency in
changing environment (*14*) Since transects are larger than quadra

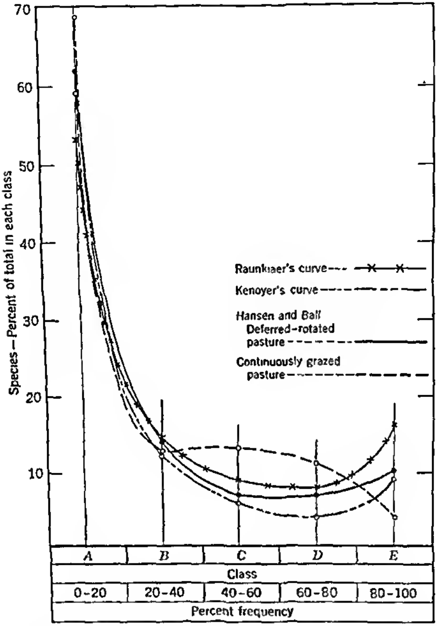


FIG. 20. Frequency-index curves for various land units. Raunkiaer's curve is derived from sampling many areas in northern Europe, Kenoyer's curve from samples of 51 different areas near Lake Michigan. Data for the curves by Hanson and Ball are from areas in Colorado. The curves compared are based upon the following data:

Source of Data	*Frequency-Index Class* (Percentage of total species in each class) *A*	*B*	*C*	*D*	*E*
Hanson and Ball (*15*)					
Deferred rotation pasture	62	14	7	7	10
Continuously grazed pasture	59	13	13	11	4
Kenoyer (*20*)	69	12	6	4	9
Raunkiaer (*26*)	53	14	9	8	16

fewer are needed for a given degree of vegetal variability Four types of transects are commonly used in range studies

Strip Transect. The strip (or belt) transect is a long, rectangular area of uniform width, the actual dimensions being determined by the kind of vegetation and nature of the problem (*1*) In grassland the width may not exceed 6 inches, in brush and woodland it may vary from 3 to 25 feet The length is determined by the needs Strip transects may be made permanent by staking at suitable intervals A steel tape may be used to delimit a narrow transect by mapping an equal strip of the vegetation on both sides On larger strip transects *the boundaries are marked by stakes and cord and each square segment is suitably divided to facilitate mapping*

The plant data are recorded as on a chart quadrat By dividing the strip into convenient intervals the data can be treated statistically Permanent strip transects are recommended, since changes in vegetation caused by management can readily be detected with minimum labor in remapping

individual species of a plant community. A steel pin about 18 inches long is projected vertically through a wooden board having 10 borings spaced 2 inches apart (Fig. 21). Each time the pin strikes a plant on its downward path, a "hit" is recorded.

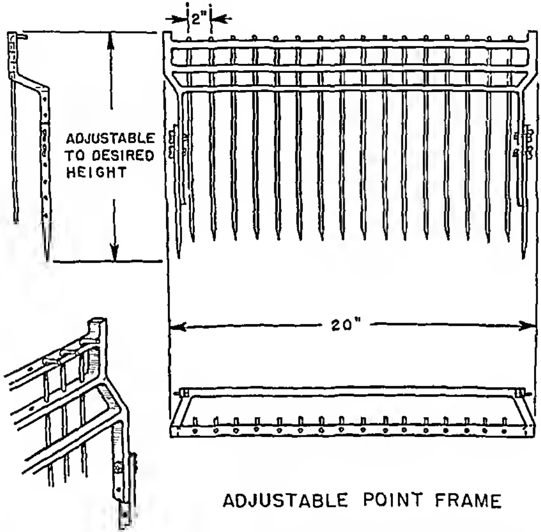


FIG. 21. Sketch showing construction of a point-observation transect frame. Ordinarily the borings through which the pin is systematically inserted are spaced 2 inches apart.

The point-observation transect has the following advantages: it requires vegetal measurement at specific spots and avoids percentage composition estimates; it may become nearly random measurement and makes subsequent statistical analyses possible; it can be employed at any degree of intensity desired, including soil observations at definite points. Its disadvantages are: field workers are not too familiar with this method; it focuses attention on a spot and requires many observations for a representative sample; it is time-consuming in single-stalk vegetation.

The point-observation transect is especially well suited for determining survival of seedlings, as in revegetation studies

Bisect The bisect is a line transect along which a trench has been dug to show a vertical section of plant tops, roots, and soil profile The entire plant system may be sketched to scale on squared paper The exposed subterranean parts should show character and comparative depth of roots of individual species in relation to top growth, relative abundance of roots in the different soil horizons, and the effect of a particular grazing system on top root relations

Animal Control Plots

Various plots to control grazing pressure either supplement quadrats and transects or are employed independently The more popular control plots are relatively large and serve to determine the effect of grazing pressure

Enclosure Plots Fenced enclosure plots determine the effect of different grazing systems on vegetation and soil and note grazing capacity of little understood range communities The enclosures vary from 1 to 2 rods square to 25 acres or more, depending on the nature of the study and the animals grazed They may be cropped closely or conservatively, they may be pastured by domestic stock, big game, or rodents The largest enclosures—25 acres or more—are commonly used for cattle A somewhat smaller acreage is used for sheep or big game Rodent enclosures are seldom larger than 1 acre Permanently established quadrats or transects may be set up within the enclosure to obtain quantitative changes in the vegetation

Exclosure Plots Experimental units that are fenced to exclude plant-eating mammals are called exclosure plots or "natural areas Their chief purpose is to study rate of recovery of depleted vegetation or natural trends of succession (*5*) Small exclosure plots—1 or 2 rods square—may be located on fenced experimental enclosures to provide information on the effect of grazing *vs* complete rest of the range As a rule, exclosure plots lose their value in a few seasons, because of excessive accumulation of mulch, hence a new sequence of exclosure plots may be established at about 5-year intervals

Seasonally Protected Plots These are fenced areas within enclosure plots designed to provide special manipulation of the grazing factor during different parts of the season The ideal seasonally protected plot consists of three contiguous segments the first is divided into several plots, each of which is opened to grazing at different seasons, the second segment is permanently closed to grazing, and the third is closed to grazing during prescribed years (*14*) Protected

plots are especially useful where two kinds of domestic stock are grazed, because the effect of each kind of animal on the differnt forage and browse species can be ascertained.

Hurdle Plots. These are usually enclosures ranging in size from about 4 x 4 feet to 20 x 20 feet. The smaller plots, termed "cages," are portable units built with a rigid steel frame covered with wire

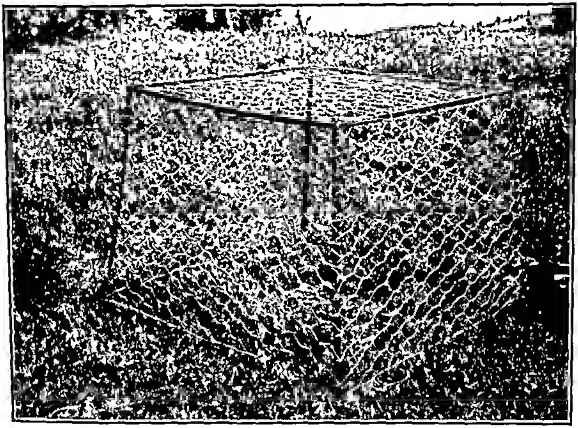


Fig. 22. Portable 4 x 4 foot wire cage, with steel frame covered with wire netting. Such a cage changes the enclosed environment imperceptibly over a short period.

netting (Fig. 22). The larger plots, termed "panels," have sides made of separately built units or gates. They are constructed of wooden or steel frame to support wire netting and should not be overly bulky lest they influence the environment (*10*). When in place, the panels are securely fastened at the corners to form a square.

The cage plots may be clipped at predetermined intervals during the growing season to determine forage composition and yield. On the panel plots, quadrats may be established on which forage may be clipped or otherwise studied as on cage plots. To ascertain forage utilization, quadrats established on unprotected (grazed) areas may be clipped and the yield compared with that produced on the protected quadrats or cages. The number of replications needed can be determined by appropriate statistical analysis.

Camera Sets These are positions set up for repeated photographing of the identical area within a season or at intervals over several seasons (*41*) In this way pictorial impressions are obtained, which could not be acquired by description The advantages of camera sets are speed and accuracy The location should be permanently established with iron stakes, and the vegetation should be rephotographed from the same height and exact direction, preferably at the same season and time of day The method is especially useful in recording successional changes under different biotic and physical conditions The author has used the camera set to advantage in studying succession on chaparral burns

Field-Sampling Problems

Regardless of the method of plot inventory employed, sampling the forage cover presents difficulties, because of the many variables encountered on range areas, even those of uniform appearance Within any fairly homogeneous area there will be some variation, such as a meadow, woodland, or glade, or differences in slope, soil, or past usage The more elements present, the greater the chance for variation in the vegetation

How to treat these variations and other pertinent biological problems is a subject in itself—biometrics, the science of statistics as applied to biological observations It is beyond the scope of this book to cover this subject However, since biometrics is a highly useful tool for the range technician, a few points deserve discussion, particularly those concerning sampling

Sampling range vegetation by plots usually aims at obtaining information applicable to an area as a whole, therefore, the plots must measure both the average condition and the variability and thus represent the population Too few or the wrong kind of samples may produce misleading results Snedecor (*34*) recognizes three objectives that should be met in sampling *First*, the sample should yield an unbiased estimate of the population mean This objective is met by random sampling *Second*, estimates from the sample should be as accurate as possible for the time and money spent *Third*, the method used should permit tests of the accuracy of the estimate Since such calculations are founded on the laws of chance, they are most frequently applied only where random sampling is employed and the populations or the means of the subsamples are normally distributed

Often the range technician is confronted with the problem of sampling an area in which some of the variation can be anticipated Let us consider, for example, a range area of rolling topography where

a measure of the average stubble height of a grazed area is desired. Since grazing animals tend to concentrate in the swales, the area may be subdivided into swales and upland, and the desired measurements randomly made in each of these subunits. The result would be a "stratified" random sample and as such would meet the fundamental principle of randomness. Stratification is merely a device that divides the parent population into subpopulations of approximate homogeneity, thus reducing the total number of plots necessary to obtain equally reliable estimates.

Size and shape of plot are determined by the nature of the study. Size of plot depends upon the kind of vegetation, its distribution, its density, and the time that can be devoted to sampling. The shape of the plot is somewhat flexible, but several studies have indicated that a plot longer than wide is frequently more efficient than a square plot.

The number of plots needed for a given degree of accuracy can be estimated by use of formulas such as are found in publications dealing with statistics (*4, 34*). These references should be studied by the research worker as he encounters statistical problems.

Not all plot records or other range data require intensive statistical analysis to obtain usable answers. However, statistical procedures have been designed to meet the kind of problems encountered in range studies. They often make this work effective. Every range technician should be familiar with biometrics and with its uses as they apply to range studies.

Environmental Influences

The discussion of forage yield and maintenance of the range plants often refers to the effect of various climatic and physical factors of the environment.

Briefly, all environmental factors are embraced under the following headings: *climatic*, or solar and atmospheric phenomena such as precipitation and humidity, temperature, light, and wind; *physiographic*, or the earth's configuration; *edaphic*, or the soil and its characteristics; and *biotic*, or the community influences of plants and animals, including man.

Climatic Factors

The atmospheric and solar phenomena of a region combine to constitute the climate. Precipitation is locally the most important single climatic factor, but temperature, light, and air movement are also influential.

In one way or another water is involved in practically all life processes. Vegetation is dense or sparse depending on the moisture available in the soil and on the atmospheric humidity which directly affects water loss from the plant. Grasslands are usually associated with areas of low to moderate precipitation, mostly received during the growing season.

Precipitation, atmospheric temperature, and wind movement combine to delimit plant and animal distribution over the earth. Temperature is a vital over-all factor in determining distribution of organisms, whereas precipitation has a somewhat more local effect. Each life process in plants has its maximum and minimum temperature limits and its optimum temperature range.

Light, that is, radiant energy, also affects distribution of plants and profoundly influences their form and rate of growth. Under natural conditions the growth rate of well-rooted plants is largely determined by the duration and intensity of the illumination. Understory plants, for example, grow rapidly early in the season under deciduous forest before the trees have formed fully developed leaves to sift out much of the sunlight. In temperate climates a mixed population of natural vegetation tends to flower and fruit at different periods; spring beauty (*Claytonia* spp.) and various buttercups (*Ranunculus* spp.) are referred to as "short-day" plants, because they flower and fruit in the spring when the hours of illumination are relatively short. In contrast, "long-day" species such as rabbitbrush (*Chrysothamnus* spp.) and big sagebrush (*Artemisia tridentata*) blossom and fruit in the autumn. Many species are intermediate in illumination requirements. A range that contains both "short-day" and "long-day" forage species is useful because the period of maturity extends over a longer season than that of a pure stand, hence the nutrient pattern is superior.

Wind movement affects plant development by its mechanical stresses. Vegetation is dwarfed in dry regions of strong winds, and tree trunks lean away from the prevailing wind direction. In sand-dune areas the vegetation is typically composed of perennial grasses with long, branching rhizomes. As the wind builds up sand here and removes it elsewhere the rhizomes grow upward or downward to maintain fairly uniform levels, perhaps in response to temperature and moisture.

Physiographic Factors

Altitude, slope, exposure, mountains, plateaus, and plains variously affect climate, soil, and vegetation. The amount of precipitation, soil moisture, incidence of light, and wind direction are much influenced by

physiography. Slope and exposure affect the amount and intensity of the solar radiation and also the degree of erosion. Range-management practices receive their severest tests on areas of rugged topography.

Edaphic Factors

These embrace all soil features. The most striking vegetal consideration is the supply of soil water and nutrients to the plant roots. Several factors influence the available soil water, such as rate of infiltration, distance to the water table, and the capillary power of soils to raise stored water. Availability of the water supply and the salt content of the soil solution greatly influence the character of the plant cover (*35*). Thus xeric vegetation occupies the desert; hydric species inhabit wet soils; mesic plants predominate on soils of moderate water supply; halic species inhabit salt marshes or saline soils. The better pasture lands have fairly deep, well-drained, and moderately mature soils, with accessible moisture during much of the growing season (*8*). Maturity of soils can be judged best by examination of the soil profile.

Soil Profiles and Soil Horizons

The soil profile (a section cut vertically through the soil) shows differences in color, texture, and certain other features. The profile of most soils is composed of three to several fairly distinct layers, or horizons; the lower ones contain varying amounts of the substances leached from the layers above. The horizons are strongly developed in some soils and weakly in others (*38*). Figure 23 illustrates a hypothetical soil profile with several well-defined horizons. No one soil type would necessarily have all the horizons shown, but every soil has some of them. *A*, *B*, and *C* are the principal horizons of the soil profile. Collectively, horizons *A* and *B* compose the *solum*, or true soil, which is formed by the soil-building processes. Horizon *C*, which lies directly under the solum, refers to the weathered parent material or unconsolidated rock. *A* is referred to as the *leached zone*, because it is relatively low in colloids and bases; *B*, the subsoil, is termed the *zone of concentration*, because it usually retains many of the colloids and bases leached from horizon *A*. More detailed study reveals that horizon *A* is composed of various subdivisions, such as A_{00} and A_0 (Fig. 23). Desirable range condition is judged partly by the thickness and state of decomposition of the organic debris lying above the A_1 soil layer. This mulch layer is effective in maintaining high infiltration capacity of the soil, in preventing excessive surface evaporation, and in favoring establishment of seedlings.

Certain other factors are also used in classifying soils (*19*). The organic matter, for example, imparts colors ranging from black to light brown. Certain minerals may also influence color; oxidized iron compounds impart a red or yellow cast to soils, whereas the concentration of salts on the surface give soils a white color.

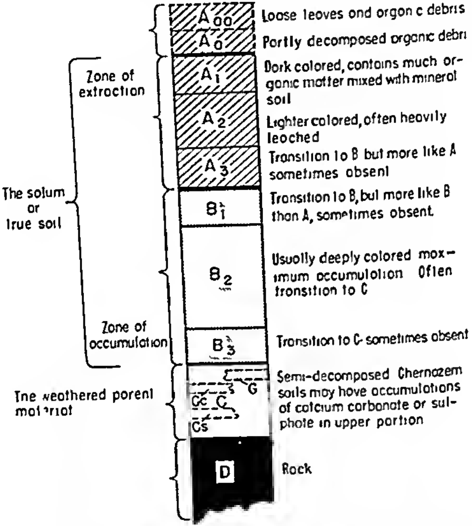


FIG. 23. The main soil horizons and their subhorizons designated respectively by letters and numbers such as A_{00}, A_0, A_1, B_1, etc. The zone of extraction and the zone of accumulation are shown lying above the weathered parent material.

The character of soils is also profoundly influenced by their texture, which refers to the size of the individual soil particles, and by the soil *structure*, which concerns the manner in which the soil particles

are arranged, together with the soil *colloids* or finer fraction of the organic and inorganic soil particles All these factors determine soil classification

Biotic Factors

These are the factors that react both on the organisms of the community, including plants and animals, and on the habitat itself

The biotic relations that take place within a community are *competition*, as for moisture, nutrients, light, space, *commensalism*, including beneficial and harmful animals and plants—bees, grasshoppers, rodents, livestock, bacteria, lianas, *symbiosis*, or intimate association between diverse organisms such as lichens (algae and fungi), and *culturalism*, where man has converted native cover to cultivated crops (*3, 8*) Biotic factors are often more influential than other factors in molding the structure of the vegetation

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Chapter 5

PHYSICAL AND VEGETAL CHARACTERISTICS OF UNITED STATES GRAZING LANDS

Range practices and problems in the many diverse regions of continental United States cannot be clearly understood without a knowledge of their physical and vegetal characteristics.[1] The physical considerations are concerned with topography, climate, and soil; the vegetal phase primarily deals with the vegetal composition of the various natural associations or "types." Climate is the over-all factor in delimiting the associations, whereas a combination of climate, topography, and vegetation, by their reaction on the parent rock materials, account for the building of soil.

The character and luxuriance of the plant associations in the eastern half of the United States are due mainly to abundant precipitation, favorable growing temperatures, and productive soils. The drought-enduring characteristics of the vegetation of the western half of the country are caused by lighter annual precipitation, rugged topography, and less well-developed soils. These restrictive growth factors indicate the need of conservative range use.

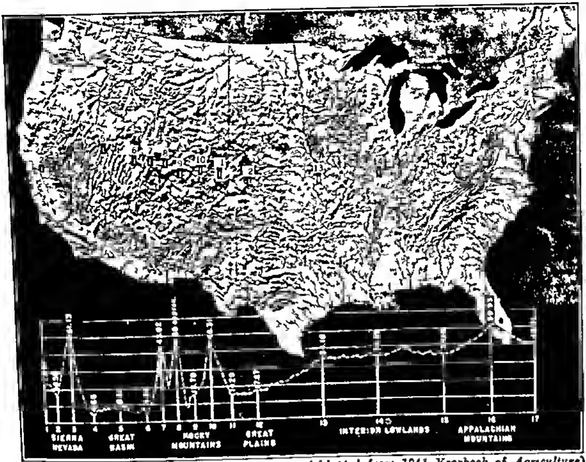
Physical Considerations

Topography

The lands of the United States are crossed from north to south by the coastal plains and plateaus of the Appalachian highlands in the East and by the much higher Rocky Mountain, Sierra Nevada, and Cascade ranges in the West (Fig. 24). The starting point of these ranges, slightly west of the 100th meridian, divides the continent into the eastern lowland and the western highland. The vast contrast in topography in the eastern and western regions largely explains the wide differences in the climate and vegetation.

[1] Some phytogeographical and other terms used in this and later chapters are presented at the end of this chapter.

Topography profoundly alters the climate and, within any latitudinal zone, largely determines the precipitation pattern. The Sierra Nevada-Cascade Mountains, rising to some 14,000 feet in elevation,



(Adapted from 1941 Yearbook of Agriculture)

FIG 24 Annual precipitation (inches) as influenced by topography along a course near the 39th parallel from San Francisco to Denver, Columbus, and Atlantic City. The large and abrupt differences in precipitation and temperature induced by topography form an especially important climatic feature in the arid region.

STATIONS

1	San Francisco Calif	25	10	Corona Col	11 660
2	Sacramento Calif	69	11	Denver Col	5 292
3	Cisco Calif	5 939	12	Goodland Kan	3 689
4	Fallon Nev	3 965	13	Leavenworth Kan	842
5	Wells Nev	5 628	14	Springfield Ill	592
6	Low Utah	4 602	15	Columbus Ohio	748
7	Silver Lake Utah	8 700	16	Somerset Pa	2 128
8	Washington Longlake Utah	10 300	17	Atlantic City N J	13
9	Glenwood Springs Col	5 758			

impede eastward-moving storms and favor heavy precipitation on the west slopes and aridity of the Columbia River Plateau and the Great Basin region (*1*). Likewise, each mountain range eastward promotes heavy precipitation on the western slopes and aridity on the slopes and

valleys to the east In many instances the east-side valleys may receive no more than 5 inches of precipitation per year, whereas the west mountain slopes, only a few miles away, may receive 40 inches or more No such contrast in precipitation occurs within short distances in the eastern half of the continent, because of the absence of lofty mountains

Topography may also modify temperatures and thereby greatly influence the character and production of forage or farm crops In semiarid country, for example, "humid islands" supporting quaking aspen, ponderosa pine, and fir may alternate with a sagebrush covered floor These summer-cool timbered areas receive a deep blanket of snow in winter and are primarily useful for growing wood and forage and as watersheds Much of our civilization depends on these humid islands for culinary, livestock, and irrigation waters, settlements were often established near the mouths of canyons and at the bases of mountains. With the water available during summer months, an irrigation agriculture was established that has stabilized farming and stock raising on the adjacent arid lands As long as the watersheds are not impaired, irrigation agriculture is secure Unfortunately, stream flow has become erratic in many places because of unwise exploitation of the land

Climate

Among all climatic factors, precipitation most strongly influences the character of the plant cover as well as the grazing capacity and management of range lands

A precipitation map of the United States shows that the West receives only about one-third as much annual rainfall as the East (Fig 25) A line drawn through Amarillo, Texas, and North Platte, Nebraska, both of which receive about 20 inches of annual precipitation, divides the country into two distinctive climatic regions (2) East of this line the precipitation reaches 35 inches in the corn belt and 50 inches or more in the southeastern states West of the line precipitation stays below 20 inches, except in some zones in the Rocky, Cascade, and Sierra Nevada Mountains The great semidesert region from southwestern Arizona to southeastern Oregon and southern Idaho receives less than 10 inches The zones of lowest rainfall are characterized by high day temperatures, low relative humidity, brisk, drying winds, intensive evaporation, and correspondingly high transpiration of the vegetation The higher temperatures in the southern arid range bring about much more rigorous growth conditions there than in the northern areas of similar rainfall

FIG. 25 Precipitation provinces of the United States The largest province of heavy rainfall is in the Southeast In the West northern California, Oregon and Washington receive the heaviest precipitation and the Southwest the lightest Note the large irregularly shaped land patterns in the western range country that receive less than 10 inches of precipitation

The seasons of greatest precipitation vary widely in the West In the valleys and foothills of California a large part is received in the winter as rain In the Great Plains much of it comes in spring and summer, in the higher northerly range mostly as snow, and in the mild climated Southwest nearly all as rain in summer and fall

Forage production in the West is greatly affected by deviations from the normal seasonal or annual precipitation Droughts are frequent and severe Some 3 to 4 years out of every 10 are drought years over large areas which receive only 75 percent or less of the normal precipitation (2) Rarely is there a year when some region is not abnormally dry The resulting fluctuation in forage production has prompted a study concerned with the appraisal of range forage production on the basis of current rainfall

Beginning in 1924 the Bureau of Agricultural Economics tried out methods to correlate annual and seasonal precipitation with forage yield and condition of the livestock Gathered voluntarily by 2000 ranchers scattered over the West, the data have been published by the Bureau and in livestock trade journals Forage production and condition of the animals are described numerically 100 or more denotes excellent or unusually favorable for range and stock, 90 to 99 very good, 80 to 89 good, 70 to 79, fair, 60 to 69, poor, 50 to 59, bad, and 49 or less very bad (4) For 11 of the 17 western states the combined amount of precipitation in any current season and preceding year accounts for 65 to 78 percent of the variation in forage yield The correlation in this combined influence in forage yield and livestock condition was found high in Region I, which includes the northern Great Plains southward to Colorado and Kansas (Fig 26), moderately close in Region II, which embraces the southern Great Plains all of Texas, and most of New Mexico, moderately close to unsatisfactory in Region III the Southwest including *Arizona Nevada* and Utah, and low to unreliable in Region IV, embracing Idaho and the Pacific Coast states of California, Oregon, and Washington This regionally low correlation may be caused by such factors as abnormally high summer temperature strong drying winds high evaporation and soil types that lose moisture readily Additional study of these relations seems justified

Soils and Forage Production

Both regionally and locally, soils may differ chemically and physically to such an extent as markedly to influence the kind and luxuriance of the vegetation Range soils may and often do indicate what special grazing practices should be *employed for their conservation*

In general, the more mature deep soils of the eastern states, where

formation has been relatively rapid, absorb and retain a large proportion of the precipitation. Such soils tend to be less subject to erosion, and they produce larger crops than the characteristically thinner and younger soils of the West. The soils on the better sites of mountainous areas may be sufficiently deep and productive for economic reseeding to suitable forage plants. Desert soils, on the other hand, since they

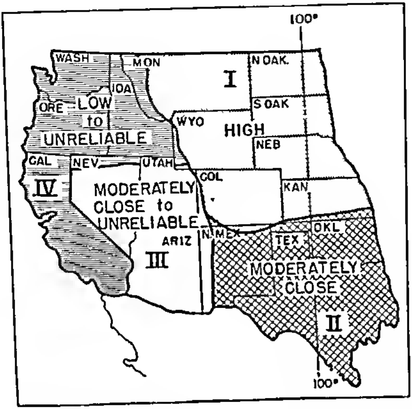


FIG. 26. Correlation between precipitation and current range forage yield in four western regions

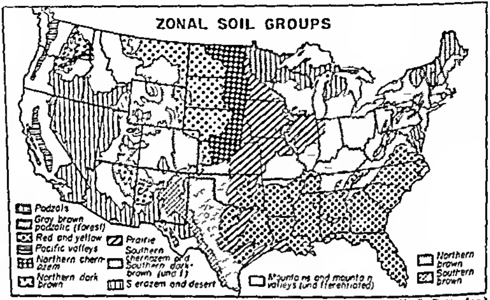
receive little precipitation and are exposed to long periods of high temperatures, have but a scanty plant cover. Some are so alkaline or saline that they support a selective plant life such as rabbitbrush and saltbushes.

In coping with range problems, some knowledge of the characteristics and distribution of the soil zones is helpful. A soil zone is composed of many soil types, each of which influences the local quality of forage and the management of the land (*7, 11*).

Major Zonal Soil Groups. Some twelve major soil zones have been recognized in the United States (Fig. 27). Each is delimited by distinctive climatic regions and is modified by the action of three processes: calcification, podzolization, and laterization.

Calcification. The calcification process of soil development occurs under a cover of grasses or grasslike vegetation in regions of rather

restricted precipitation. The vegetation absorbs and brings bases and some phosphorus from the lower horizons to the surface. The soil does not become conspicuously acid, and the colloids remain relatively immobile, since they are largely saturated with calcium. Calcification gives rise to such important zonal groups as Prairie, Chernozem, Chestnut or Dark Brown, Brown, Gray, and the Sierozem and Desert soils.



(U S Dept Agr)

Fig 27. Distribution in the United States of the twelve major soil zones. Soil types occurring within the zonal group are particularly numerous in the West, *because of the rugged topography and variable climate.*

The Prairie soils, having been developed in a region of relatively high precipitation, have no horizon of calcium carbonate. They are highly productive for grasses and grains. The northern and southern Chernozem soil zones, located immediately west of the Prairie soil zone in the drier portion of the midwestern region, have a horizon of calcium carbonate (Fig. 27) and are also relatively productive. Westward, where the climate becomes progressively drier and the vegetation sparser, the soils are thinner and lighter in color. Increase in aridity brings about the Dark Brown and Brown soils of the mixed prairie and short-grass associations, the Gray soils of the semidesert, and finally the Sierozem and Desert soils, which are the lowest in organic matter. Grazing is the chief industry west of the Prairie soil zone.

Podzolization. The podzolization process is primarily active in the humid, northern, low-temperature region, the area bordering the northern portion of the Prairie soil zone and eastward. It develops

typically under conifer and heath (Fig. 27). The heavy precipitation removes the soluble salts, including the carbonates of calcium and magnesium, leaving the soil very acidic. The Podzol soil zone, when cleared and fertilized, produces fair yields of grass and cereal crops.

The more extensive Gray-Brown podzolic soils that occur south of the true Podzol zone (Fig. 27) have developed under deciduous forest and a moist, temperate climate. These soils are only moderately acidic and are much more productive than the true Podzols. Large areas are used for growing corn, wheat, and pasturage. Here industrial development is conspicuous.

Laterization. The laterization process is confined to the warm, humid climate of southeastern United States. It consists of the removal of silica and takes place under the influence of podzolization. The soils are designated as Yellow and Red (Fig. 27). The Yellow soil unit supports the coniferous growth of Coastal Plains from North Carolina to Texas. The relatively more productive Red soil unit has a cover of deciduous and coniferous forest and lies immediately north of the Yellow soil zone. The colors of red to rose, and yellow are imparted to the soil by the comparatively insoluble iron and aluminum. Because of rapid weathering, bases are readily released; and, since the vegetation brings abundant bases to the surface, the plant cover is luxuriant. A wide transition is found between the Gray-Brown Podzolic and the Lateritic soils. No true Laterite soils occur in the United States, but the Red and Yellow Lateritic soil groups mentioned have many characteristics of Laterite soils. Much of the forest of this region has been cleared for growing cotton, tobacco, peanuts, and pasturage.

Interzonal soil groups occur commonly. They include areas of alkali or saline soils, which at some time received an excess of salts and which are most common in the West. They also include the bog soils, where peaty materials have accumulated.

Vegetal Considerations

The diversity in topography, climate, and soils in the country gives rise to many associations of natural vegetation. The cover ranges from deciduous and coniferous forest in the East and Southeast to tall and short grass in the Midwest and semiarid West; from alpine glade, meadow, and coniferous forest in the Rockies and the West Coast mountains to sparsely vegetated deserts in the Southwest. It is important to know the character and distribution of the plant associations, because they often indicate the need of specifically designed range-management practices.

Vegetation the world over may be divided into three broad growth forms grasses, shrubs, and trees In the United States, grassland covers 38 percent of the area, desert shrub 14 percent, and forest 48 percent (Fig 28) The plants of these three life forms compose extensive

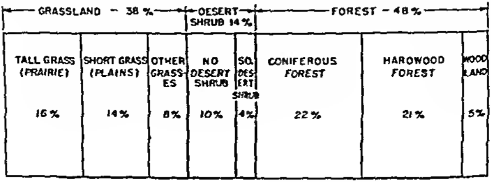


Fig. 28 Percentage of grassland desert shrub and forest land, and their broader segregates, in the United States

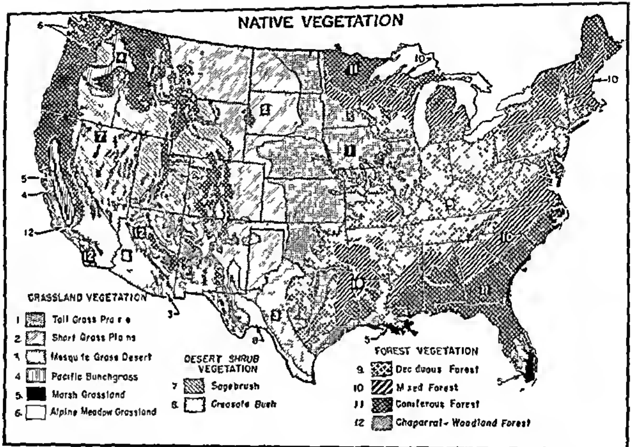
formations, the larger associations of which are shown in Fig 29 The classical paper, "Natural Vegetation," by Shantz and Zon (*10*) was freely consulted in preparing this section

Grassland Vegetation

Between the eastern and western forest regions, and reaching from Canada to Mexico, lies a vast grassland or prairie Most of this region supports bunchgrasses, varying in botanical composition and in height largely according to the amount of precipitation received The differences in stature of the associations has led to the terms "tall grasses," such as big bluestem, "mid grasses, such as the wheatgrasses and June grass, and "short grasses," such as buffalo grass and blue grama (*5*, *13*) [2] Few woody plants are found on the tall grass and the mid grass associations, but the low-rainfall regions have been extensively invaded by such shrubs as creosote bush, mesquite, big sagebrush, greasewood, and rubber rabbitbrush Most grasslands are characterized by frequent summer rains Regions that enjoy mild temperatures and adequate rainfall in the winter, as on the Pacific Coast, support winter-annual grass and forb growth which matures at the start of hot, dry, summer weather In contrast, in the eastern and northern prairie region, vegetal dormancy is brought about by low temperatures

The United States has six major grassland associations (1) tall grass prairie, (2) short grass plains, (3) mesquite grass desert and desert

[2] Scientific names of plants mentioned are given at the end of this chapter



[*Adapted after Shantz and Zon (10)*]

FIG 29 Distribution of the native vegetation of the United States The approximate delimitations of the chief associations of each of the three great formations—forest, grass, and desert shrub—are indicated The grassland vegetation consists of six associations

grass savannah, (4) Pacific bunchgrass, (5) marsh grassland, and (6) alpine meadow grassland (*10*)

1 **Tall-Grass Prairie** Lying essentially east of the 100th meridian, in the Mississippi Valley, the original area of some 250 million acres of tall grassland has almost all become farm land (Fig 29) The 20 to 40 inches of precipitation and the deep, fertile soil indicate heavy yields of native grass and superior farm land The Prairie soils are essentially of the Chernozem group in which little of the moisture is lost to the subsoil The grass is dense, but in springtime the landscape is colorful with blossoming forbs The most typical grasses are big bluestem, little bluestem, Indian grass, needlegrass, slender wheatgrass, needle-and-thread, and Junegrass (see Chapter 9) The natural pastures are in good condition where grazed or mowed rationally, overgrazing has caused thinning out of the grass and invasions by useless weeds (*14*) Long droughts encourage sand dropseed, western wheatgrass, and cacti (*13*)

2 **Short-Grass Plains** This great grassland region lies between the tall grass prairie and the Rocky Mountains and extends from Canada to central Texas and southern New Mexico (Fig 29) Most of the 285 million acres are grazed annually This natural grassland produces nearly one-third of the nation's range beef The line of demarcation between the tall grass prairie and the short grass plains is not always distinct, for the moister eastern boundary supports many mid grasses and, here and there, short and tall grasses

This cover has prompted the question of whether the entire short grass plains may not merely be a modified mid grass association and whether livestock grazing may not be the cause of the present prevalence of short grass (*15*) Grazing is probably a factor in species composition where rainfall is heavier (12 inches in central Montana and 22 inches in central Texas), but drought enduring short grasses evidently constitute the climax cover in the vast low precipitation portion of the plains country Larson (*8*) reasoned that the short grass plains represent the true climax, because historical records show that short grass dominated the plains when they were first seen by white man, that wild animals originally utilized these lands about as fully as domestic animals have later, and that short grass dominants endure close grazing remarkably well The most characteristic grass dominants are Buffalo grass blue grama, western wheatgrass, sand dropseed, ring muhly, needle and thread, western needlegrass galleta, and Junegrass The open sod of buffalo-grama grass extends over eastern Colorado and western Nebraska and through Kansas and Oklahoma to the Panhandle of Texas where it provides immensely important pasturage In

Montana and Wyoming, fringed sagebrush, threadleaf sedge, and June-grass alternate with blue grama, in New Mexico and other low-rainfall areas, overgrazing causes invasions of cacti, Russian thistle, and broom snakeweed

The plains grasses are palatable and nutritious throughout the year The stand as a whole has been maintained in fair-to good condition despite frequent droughts and close grazing Dryland farming, though generally unsuccessful, has uprooted the sod in many localities, despite the widely recognized fact that grazing provides the best permanent use of these lands

3 **Mesquite-Grass Desert and Desert-Grass Savannah** This desert cover is characterized by distinctive climate and plant composition

The most typical mesquite grass desert lies in Arizona, New Mexico, Texas, and Mexico (Fig 29) Growth begins in July with the coming of rains which bring from 12 to 18 inches of precipitation a year Areas of pure grassland are small, because of encroachment of brush, especially creosote bush, mesquite, catclaw, soaptree yucca, and Emory oak The most widespread and important grasses are black grama, Rothrock grama, mesquite grasses, and three-awn These xeric plants are commonly associated with annual gramas and forbs, and their dominance varies according to soil type and drainage The pasturage rating is fairly good, since this association supports up to about 20 cattle per section of land in years of normal rainfall Overgrazing has caused marked decline in quality and grazing capacity of many lands, but the less degraded areas respond well to improved management

Southeastward, where the annual rainfall is 20 to 30 inches, lies the desert-grass savannah (Fig 29) It occupies the region in Texas south of the Red River and east and south of the plains border, it also extends over the lower southwest region of the high plains of Texas Mesquite, the dominant tree, either forms a woodland or a scattered stand Prickly pear, fringed sagebrush, and many other small, thorny trees and bushes are plentiful Buffalo grass, the gramas, and curly mesquite are the most useful forage grasses, and annual three-awns are locally abundant (*6*) Originally the vegetation was mostly tall grass In many places mesquite and other brush species now form a closed woodland The region furnishes fairly satisfactory grazing, and the mesquite tree provides fence posts and fuel The areas of deeper soils are cultivated for cotton, corn, and grain sorghums

4 **Pacific Bunchgrass** Mid grasses of the perennial bunch-growth form occur in the Pacific Coast states and in Idaho, Montana, and

Nevada (Fig 29) Dominant species are needlegrass, oatgrass, pine bluegrass, California melic, Junegrass, and beardless wild rye In the moister and cooler coastal strip and in the high mountains, species of wheatgrass, bluegrass and fescue are common

In the valleys and foothills of California some 25 million acres, formerly occupied by native bunchgrasses, have been largely replaced by mediterranean annuals, partly as a result of overgrazing and perhaps of burning Representative of these annuals are wild oat, soft chess, red brome, ripgut, foxtail fescue, Pacific fescue, and mouse barley Among the more aggressive, introduced palatable forbs are redstem filaree, broadleaf filaree, and bur clover Abundant also are native species of larkspur, phacelia, tarweed, and many other unpalatable plants The interior foothills and valleys support an almost pure stand of annual species On a sample area in San Joaquin Valley, for instance, up to 95 percent of the grassland consisted of annual plants, of which 63 percent were exotics (*12*) This change in cover composition is not altogether uneconomical, because the winter annuals provide much early winter and spring feed Forage yield varies seasonally, because of variations in rainfall and these fluctuations are a factor in management

In the Palouse prairie of north central Oregon, eastern Washington, and adjacent Idaho (Fig 29) there grows a high quality forage cover of bluebunch wheatgrass, Idaho fescue, Junegrass, pine bluegrass, giant wild rye, and needle-and thread Several of these species are also important components on ranges of western Canada, Montana, Utah, and Nevada Overgrazing has resulted in replacement of these grasses by big sagebrush, fringed sagebrush, downy chess, and other inferior plants

5 **Marsh Grassland** This widely scattered and diversified grassland, composed both of fresh and salt marshes, lies mainly along the Atlantic and Gulf Coasts, in the Florida everglades, in the central valleys of California, and limitedly along the coast of California and Oregon (Fig 29) The fresh marshes support species of Indian rice, paspalums, cat-tail, rushes, and tule and are grazed chiefly in late summer and fall The salt marshes are occupied by salt-tolerant herbs, of which reeds, saltgrass, and pickleweed are common They are mostly grazed during the winter, and their forage rating is low

6 **Alpine Meadow Grassland** Lying near or above timberline in the West are moist areas dominated by grasses and grasslike plants (Fig 29) Typical are alpine fescue, tufted hairgrass, threadleaf sedge, rock sedge, and numerous colorful Arctic forbs Although the acreage is not large, alpine meadow grassland provides important choice forage

during summer months in the Cascade, Sierra, and northern Rocky Mountains.

Desert Shrub Vegetation

Lying between the Cascade-Sierras and the Rocky Mountains, and extending from Canada to Mexico, is a vast, inland desert of shrubs and half-shrubs, with intrusions of grassland These plants are protected for survival by the wide spacing, their small, thick leaves, spreading roots, and limited annual growth

Big sagebrush and creosote bush compose extensive but separate associations, creosote bush being confined to the extremely arid southwestern region (Fig 29)

Big sagebrush, with an area of 213,600 square miles (*6*), enjoys the widest distribution of the western desert shrub communities Here and there are found extensive areas of alkali-tolerant shrubs, dominated by winterfat, greasewood, hop sage, white sage, and species of rabbitbrush and saltbush Scattered throughout this region are such grasses as needle-and-thread, western wheatgrass, bluebunch wheatgrass, Indian ricegrass, giant wild-rye, galleta, blue grama, and species of bluegrass and bromes The big sagebrush region is extensively grazed in winter, spring, and fall

The creosote bush desert extends from southeastern California to the Gulf of Mexico over some 133,870 square miles It embraces the most severe desert of the West, with a rainfall ranging from 2 to 15 inches Evaporation is high, and summer temperatures often reach 100° to 125° F The *vegetation is chiefly composed of five shrub associations* creosote bush, desert saltbush, yucca, cactus, California sagebrush, and mesquite In the drier areas most of the forage consists of filaree, burclover, wild oat, desert plantain, bromes, and fescues In the heavier rainfall units perennial grasses prevail, curly mesquite, cottontop, alkali sacaton, bush muhly, and the gramas being common About half of this desert is waste range, much of the pastured portion has been severely depleted by overgrazing

Forest Vegetation

The two great regions of forested lands—the eastern or Atlantic region and the western or Pacific region—are separated by grassland (Fig 29).

Eastern Forest Region. The greater area of the eastern forest region, valleys and mountains, is primarily hardwood More than half of the 1,000,000 square miles of this forest has been converted into farms or reseeded to pastures In Indiana, Ohio, and the Mississippi

Valley, oak and hickory indicate a relatively long growing season and deep, productive soil, this area is now occupied by the best eastern farm and pasture land. Farther eastward, oak, and farther southward chestnut, tulip, and yellow poplar are indicators of productive farm and pasture lands. Northward, the boreal, coniferous forest of spruce and fir indicates a short growing season, acidic soils, and a long livestock-feeding period. In the northeastern Lake States region, Jack, red, and white pines indicate severely cold winters and a frost free period of only some 4 months, which is insufficient for extensive farming or economical stock raising. In contrast, the southeastern forest region, with its long growing season and lateritic soils, supports many livestock on the natural forage of bluestems, paspalums, panicums, muhlys, and various forbs and browse (3).

Western Forest Region. This forest entity differs from the eastern forest region chiefly in the following respects: the stand is predominantly coniferous, the elevations are greater, precipitation is lighter, the topography is more rugged, the growing season is shorter, the forests are markedly interrupted by grassy valleys, mountain meadows, and glades, the original area is essentially intact, though large units have been ruthlessly logged and burned, only limited areas have been converted into farms or stock ranches.

Coniferous Mountain Forest. In the higher mountains perennial bunchgrasses are common, notably species of bluegrass, brome, fescue, needlegrass, and wheatgrass. Interspersed are various palatable perennial forbs, such as butterweed, yarrow, cow parsnip, and dandelion. Shrubs such as currant, bitterbrush, serviceberry, and mountain mahogany are common, and some are good browse plants. Stock-poisoning forbs and shrubs occur in all parts of this timber zone. The open timber stands of ponderosa pine produce much more forage than the characteristically dense stands of Douglas fir, lodgepole pine, and Engelmann spruce.

Chaparral-Woodland Forest. The chaparral and woodland associations lie at medium to low elevations. Although they are distinct entities they frequently intermingle, partly because of overgrazing and fire. This low-grazing forest is widely distributed in the West, and the grazing resources are variable (Fig. 29).

In Colorado, Utah, New Mexico, and Arizona, deciduous oaks predominate, in California, ceanothus, chamise, manzanita, scrub oak, and juniper are common. The chief value of the southern California chaparral is that of watershed protection, whereas the northern portion provides both watershed protection and grazing. Suppression of the brush to favor pasturage is difficult and expensive (see Chapter 13).

Some Phytogeographical and Other Terms Used in This and Later Chapters

Annuals or annual plants. Grasses or forbs that live only one season and are wholly dependent on seed for their reproduction and maintenance.

Bunchgrasses. Species of grasses so called because of their characteristic habit of forming bunches rather than sod.

Chaparral. A cover usually composed of a dense growth of many-branched evergreen shrubs or dwarf trees.

Cool-season plants. Grasses and other life forms that grow in the winter, early spring, or late fall, when temperatures are too low for activation of some plants.

Drought-enduring plants. Species that can grow and reproduce with limited moisture supply.

Endemic. Native to a particular country; not introduced or naturalized.

Exotic. Introduced from a foreign country; not native.

Grazing (forage) value. The worth of a plant or cover for livestock and/or game. This is determined by its palatability and nutritional rating, such as excellent, good, fair, or poor, amount of forage produced, longevity, and area of distribution.

Introduced plants. Species that have been brought in, accidentally or purposefully, from outside North America.

Invading plants. Species that come in on lands after the more stable, so-called climax plants have been diminished in the stand by drought, fire, or overgrazing. An abundance of invading plants on a range area usually connotes range depletion.

Mediterranean plants. Species developed in mild climatic areas bordering the Mediterranean Sea.

Common dominants are blue grama buffalo grass and sedges Regarded by some ecologists as having replaced the mid grasses because of overgrazing

Steppe One of the large tracts in southeastern Europe or in Asia which is generally level grassy and without trees

Tall grass prairie Also called true prairie Refers to the prairies of North America the pampas of South America the high veldt of South Africa and portions of the steppes of Russia which support grass stands 4 to 6 feet tall Bluestems and Indian grass are common components The lands typically have a drought and a cold period

Veldt In South Africa grasslands or areas only thinly forested

Warm season plants Grasses and other life forms that grow most rapidly during the frost free period and form seed in summer or early fall

Scientific Names of Plants Mentioned in Chapter

Alkali sacaton (*Sporobolus airoides*)
Alpine fescue (*Festuca brachyphylla*)
Beardless wild rye (*Elymus triticoides*)
Big bluestem (*Andropogon gerardi*)
Big sagebrush (*Artemisia tridentata*)
Bitterbrush (*Purshia tridentata*)
Black grama (*Bouteloua eriopoda*)
Blue grama (*Bouteloua gracilis*)
Bluebunch wheatgrass (*Agropyron spicatum*)
Bluegrasses (*Poa* spp)
Bluestems (*Andropogon* spp)
Broadleaf filaree (*Erodium botrys*)
Bromes (*Bromus* spp)
Broom snakeweed (*Gutierrezia sarothrae*)
Buffalo grass (*Buchloe dactyloides*)
Bur-clover (*Medicago hispida*)
Bush muhly (*Muhlenbergia porteri*)
Butterweed (*Senecio* spp)
California melic (*Melica imperfecta*)
California sagebrush (*Artemisia californica*)
Catclaw (*Acacia greggii*)
Cat tail (*Typha latifolia*)
Ceanothus (*Ceanothus* spp)
Chamise (*Adenostoma fasciculatum*)
Chestnut (*Castanea* spp)
Cottontop (*Trichachne californica*)
Cow parsnip (*Heracleum* spp)
Creosote bush (*Larrea tridentata*)
Curly mesquite (*Hilaria belangeri*)
Currant (*Ribes* spp)
Dandelion (*Leontodon* spp)
Desert plantain (*Plantago erecta*)

Desert saltbush (*Atriplex polycarpa*)
Douglas fir (*Pseudotsuga taxifolia*)
Downy chess (*Bromus tectorum*)
Emory oak (*Quercus emoryi*)
Englemann spruce (*Picea engelmannii*)
Filaree (*Erodium* spp.)
Fir (*Abies* spp.)
Foxtail fescue (*Festuca megalura*)
Fringed sagebrush (*Artemisia frigida*)
Galleta grass (*Hilaria jamesii*)
Giant wild-rye (*Elymus condensatus*)
Gramas (*Bouteloua* spp.)
Greasewood (*Sarcobatus vermiculatus*)
Hickory (*Hicoria* spp.)
Hop sage (*Grayia spinosa*)
Idaho fescue (*Festuca idahoensis*)
Indian grass (*Sorghastrum nutans*)
Indian rice (*Zizania aquatica*)
Indian ricegrass (*Oryzopsis hymenoides*)
Jack pine (*Pinus banksiana*)
Junegrass (*Koeleria cristata*)
Juniper (*Juniperus* spp.)
Larkspur (*Delphinium* spp.)
Little bluestem (*Andropogon scoparius*)
Lodgepole pine (*Pinus contorta*)
Manzanita (*Arctostaphylos* spp.)
Mesquite (*Prosopis juliflora*)
Mesquite grasses (*Hilaria* spp.)
Mountain mahogany (*Cercocarpus* spp.)
Mouse barley (*Hordeum leporinum*)
Muhlys (*Muhlenbergia* spp.)
Needlegrasses (*Stipa* spp.)
Needle and thread (*Stipa comata*)
Oak (*Quercus* spp.)
Oatgrasses (*Danthonia* spp.)
Pacific fescue (*Festuca pacifica*)
Panicums (*Panicum* spp.)
Phacelia (*Phacelia* spp.)
Pickleweed (*Salicornia* spp.)
Pine bluegrass (*Poa scabrella*)
Pines (*Pinus* spp.)
Ponderosa pine (*Pinus ponderosa*)
Prickly pear (*Opuntia lindheimeri*)
Rabbitbrush (*Chrysothamnus* spp.)
Red brome (*Bromus rubens*)
Red pine (*Pinus resinosa*)

Red stem filaree (*Erodium cicutarium*)
Reed (*Phragmites* spp)
Ring muhly (*Muhlenbergia torreyi*)
Ripgut (*Bromus rigidus*)
Rock sedge (*Carex rupestris*)
Rothrock grama (*Bouteloua rothrockii*)
Rubber rabbitbrush (*Chrysothamnus nauseosus*)
Rush (*Juncus* spp)
Russian thistle (*Salsola pestifer*)
Saltgrass (*Distichlis spicata*)
Saltbushes (*Atriplex* spp)
Sand dropseed (*Sporobolus cryptandrus*)
Scrub oak (*Quercus dumosa*)
Serviceberry (*Amelanchier alnifolia*)
Slender wheatgrass (*Agropyron trachycaulum*)
Soaptree yucca (*Yucca elata*)
Soft chess (*Bromus mollis*)
Spruce (*Picea* spp)
Tarweed (*Hemizonia* spp)
Threadleaf sedge (*Carex filifolia*)
Three awn (*Aristida* spp)
Tufted hairgrass (*Deschampsia caespitosa*)
Tule (*Scirpus* spp)
Tulip tree (*Liriodendron* spp)
Western needlegrass (*Stipa occidentalis*)
Western wheatgrass (*Agropyron smithii*)
Wheatgrasses (*Agropyron* spp)
White pine (*Pinus strobus*)
White sage (*Kochia americana*)
Wild oat (*Avena fatua*)
Winterfat (*Eurotia lanata*)
Yarrow (*Achillea* spp)
Yellow poplar (*Liriodendron tulipifera*)
Yucca (*Yucca* spp)

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HISTORICAL DEVELOPMENT OF GRAZING IN AMERICA

The history of livestock introduction—its early handicaps booms depressions range wars—constitutes a drama unequalled elsewhere In formation on the philosophy of land acquisition and ownership of its subsequent disposition and how these events influenced the develop ment of the livestock industry is necessary for a clear understanding of present day range land administration and use The events dating back to the pioneer stockman kindled the still prevalent spirit of cooperation and hospitality peculiar to graziers

Genesis of Livestock in America

The chronologies of the introductions of livestock and their subse quent distributions over the continent are shown in a schematic design (Fig 30)[1]

Livestock in West Indies and Mexico

Landing of the first livestock on the continent may be credited to Columbus (2) in his second voyage in 1493 In that year he sailed from Spain with 37 horses and mules and some cattle sheep goats, and hogs but how many of these animals endured the voyage is not known (*4*) Columbus (*12*) realizing the importance of breeding and work animals convinced his government that it should send horses and other livestock on every ship bound for the West Indies

The lure of gold and additional territory induced the conquistadors to turn from the West Indies to the mainland In 1519 Cortez landed 16 horses near Veracruz Mexico and in 1521 Villalobas Governor General of Mexico brought troops and cattle from Haiti into Mexico south of Veracruz. The animals increased so rapidly that in 1536 Mendoza (*11*) Viceroy to Mexico organized several livestock associa

[1] The author is indebted to Dr H E Bolton Professor Emeritus Department of History University of California for verifying the data and events presented in Fig 30

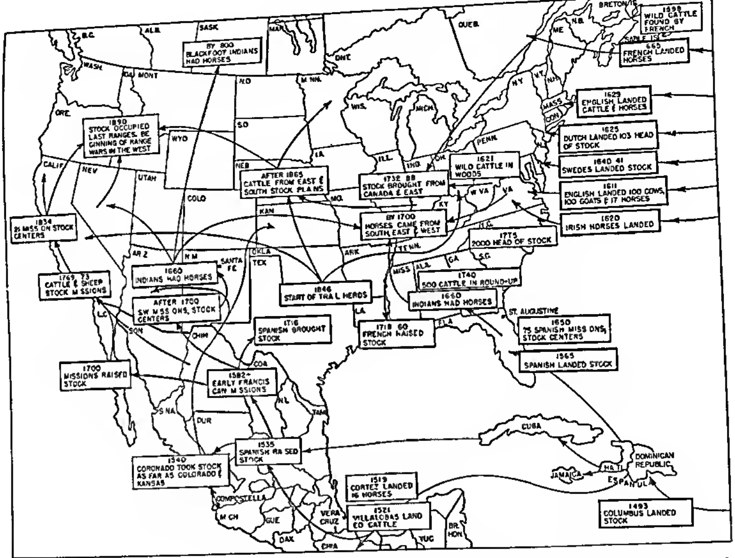

Fig. 30. Schematic design of the history of livestock introductions in North America, and expansion of the grazing industry of the United States. The heavier-lined rectangles along the east coast show the countries and dates when livestock were imported

tions, the first of their kind on the continent. By 1555 there were many fat, cheap cattle in Mexico (*15*). Within two decades after the landing of Cortez in Veracruz, the conquistadors turned northward for acquisition of additional lands. Mexican livestock were rounded up for transportation, food, and breeding purposes in this new territory (*5*).

Livestock in Western United States

Coronado, in 1540, was the first to bring livestock into what is now western United States. He journeyed through the Southwest and into Colorado and Kansas (Fig. 30), after leaving Compostela, Mexico, with 1300 horses and mules, and large numbers of cattle, sheep, and hogs. Additional Mexican expeditions soon followed. The Franciscan missions, established in northern Mexico after 1582, were helpful in extending colonies and livestock in the southwestern states. In 1609 the town of Santa Fe with its livestock grounds was founded; and in 1696 missions and stock-breeding grounds were established in Arizona. These settlements became important stock centers early in the eighteenth century (Fig. 30).

At the end of the seventeenth century Father Salvatierra had located missions and livestock in Lower California. In 1769 Father Serra founded the first California mission—at San Diego—bringing livestock with his expedition. Settlement steadily extended along the coast until, in 1834, there were 21 Spanish missions and many livestock centers in California (Fig. 30).

Livestock in Eastern United States

The first successful introduction of livestock into what is now eastern United States occurred in 1565, at St. Augustine, Florida (*13*), 25 years after Coronado had landed domestic stock in the West. Between the years 1521 and 1539 De Soto and other Spanish explorers landed horses in the Southeast; but apparently none of the animals survived.

In 1598 a French colony established on Sable Island, N. S., by Marquis de la Roche found wild cattle; these cattle were probably the offspring of animals that escaped from Spanish ships wrecked in an abortive attempt to colonize Cape Breton Island (Fig. 30). In 1611 the English strengthened their Jamestown colony by landing 100 cattle, 17 horses, and other animals, the horses brought there in 1609 having been used as food. In 1620 additional horses were introduced by the Irish, and livestock of Jamestown were thriving (Fig. 30). In 1625 the Dutch shipped cattle, sheep, and horses into New Amsterdam (New York); and in 1629 the English landed livestock in Massachusetts.

Fifteen years later (1640–41), cattle, sheep, horses, and goats were imported by the Swedes along the Delaware River. The French, showing renewed interest in their northern colonies, brought horses to Canada in 1665, and in the next decade they landed many cattle and sheep. Subsequently, numerous livestock importations were made from both the European homelands and the West Indies. By 1700 large numbers of livestock were moving into the interior.

LIVESTOCK IN INTERIOR STATES

Among the larger livestock movements was that of the French, who, between 1732 and 1788, founded farm settlements in Illinois and Indiana and drove many animals southward from Canada. They also brought many livestock into Louisiana where, in 1718, they founded the city of New Orleans (Fig. 30). By 1850 there were livestock on most of the interior frontiers.

"CAYUSES" AND WILD HORSES

Horses proved to be exceedingly well adapted to the plains, where they multiplied rapidly. The escaped animals soon became so numerous as to cause serious overgrazing. By 1660 the Indians of the Southwest had captured or stolen many cayuses and were using them extensively (*14*, *19*). Their popularity spread among the Indians everywhere, and by 1800 even the Blackfoot Indians of Saskatchewan had become adept horsemen (Fig. 30).

Early Handicaps, Expansion, and Adjustments of Range Industry

EARLY HANDICAPS

Despite the favorable foraging conditions, pioneer stockmen were confronted with many drawbacks. The Indians, by thievery of livestock and continual resistance to the settler, constituted the most dreaded early handicap. Even so, by 1830 cattle and sheep of Texas were spreading northward and contacting herds and bands in the Mississippi Valley. Although the industry lacked transportation and satisfactory markets, expansion continued because of abundant pasturage. Within the next three decades two events greatly stimulated livestock markets and production, namely, the California gold rush and the Civil War.

* An Indian pony named after the Cayuse Indian tribe which formerly occupied the Blue Mountains of Oregon. These Indians acquired horses in the early days and distributed the colts among other Indian tribes.

Gold Rush and Texas Trail Herds

Early in the nineteenth century Texans began marketing their cattle in growing midwestern cities. In 1846 many cattle were trailed to Ohio (*18*), and during the gold rush large herds were driven to California where they competed with native beef and with stock from Mexico, Arizona, and New Mexico (Fig. 30). Regardless of attacks by Indians, natural hazards, and hostilities of ranchers along the way, increasing numbers of steers from Texas reached California. Soon an excessive supply of meats and hides caused so sharp a drop in the California market as greatly to curtail livestock imports. This situation brought about a decline in livestock numbers in the state for more than a decade.

During, and for some time after the Civil War, there was again great demand for meat and animal products, and hundreds of thousands of stock were driven to market from Texas. Many animals were on the trail from 2 to 3 years, having grown out and been fattened on the way. Breeding herds were trailed as far as Canada. By 1885, when fencing and railroad transportation all but ended these trailings, more than 5 000 000 cattle had been driven from Texas (Fig. 30).

Livestock Boom

The inflationary period after the Civil War caused tremendous expansion in livestock. Pamphlets promising enormous profits in livestock resulted in investment of millions of dollars from the eastern states and the Old World. The boom affected much of the West (*17*) and was the chief factor in the sharp upswing in livestock populations (26 650 000 cattle in the 17 western states in 1890 as compared with 4 630 000 in 1870). Soon overexpansion, poor management, homesteading, and periodic droughts resulted in conspicuous shortage of feed and in range depletion. Thousands of livestock perished and untold numbers were thrown on the market at ruinous prices. Bankruptcy of companies and individuals was the rule.

Range Wars

By 1890 the last western open range was fully stocked. At that time there were 20 000 000 sheep in the 17 western states as compared with 514 000 in 1850 (*17*). The resulting competition for forage between cattle and sheep was intense, for stockmen of both factions felt they had established prior right to range they had used. The period from 1890 to 1905 was marked with many bitter struggles in which cattle raisers and sheep growers contested the right to use range. Sheepmen ser

fire to ranges when departing in the fall, cattlemen declared "open season" on sheep and herders alike In several localities many lives were lost on both sides

In the early period of this factious fury, cattlemen constructed barbed-wire fences around lands that they had acquired or were merely using, to conserve forage and water for their own animals Usually the fences enclosed far greater acreage of free range than of privately-owned land

The practice of precluding starving herds and bands of competing stockmen brought about a renewed struggle between nomadic herdsmen and settled operators and led to extensively organized "wire snipping" Although the fencing of public range was most widespread in Texas, it was also a common practice in several other states, notably the Dakotas, Montana, Colorado, Wyoming, Kansas, and Nebraska The struggle for free range was most severe and savage in years of drought When requests to remove illegally placed fences went unheeded, the wire cutters would take the law into their hands In Custer County, Nebraska, in 1884, when the Brighton Ranch Company failed to remove a fence around many sections of "no man's land," the snippers severed the wire fences and used the posts as rafters in their sod houses Although the Federal government enacted laws forbidding fencing of public domain lands, these laws were seldom enforced Eventually, the illegally erected barbed-wire fencing proved beneficial in discouraging nomadic grazing and in promoting permanent settlement According to Gard (*9*)

> The barbed wire fence played a major role in the taming of the western plains, a task in which the fence cutters were only a momentary impediment It opened the plains to homesteading, encouraged improvement of the land, and gave rise to thriving cities on what had been a few decades earlier the range of the buffalo

One of the most effective measures adopted by cattle and sheep graziers during the struggle for free range was the eventual establishment, by mutual agreement, of "dead-lines" These lines constituted boundaries mutually agreed upon by the two stockmen factions in setting aside areas that could be grazed unmolestedly by these groups Where dead-lines were not respected the molester would pay dearly for his temerity Losses of human lives and of livestock declined sharply soon after dead-lines were extensively adopted

Another highly stabilizing livestock event was the expansion, in 1905, of the national forests, a measure that virtually ended the range wars

History of Acquisition and Administration of Public Lands

The United States government was concerned first with the acquisition and later with the parceling out of small, productive land units to qualified individuals But judicious procedure in administration of arid western grazing lands had to await a relatively late date Since little of the nation s land was surveyed and none was classified to indicate its best uses it is remarkable that so many persons found suitable areas to operate Admittedly, glaring administrative errors were made yet few politicians or administrators became rich, millions of citizens found peace and contentment on the land and a struggling nation became powerful

By definition, public domain includes all lands not privately or corporately owned More concretely, the term embraces all areas federally owned that have not been set aside or appropriated for some specific uses There were no public domain lands in the original thirteen states of the East, nor in Indiana Kentucky, Ohio or Tennessee A few small parcels of Federal lands still exist in the Lake States and in the South Nearly all the remaining public domain is located in the arid West and is useful chiefly for grazing, timber and watershed protection A large acreage is desert waste Acquisition was obtained by treaty, cessions by states capture conquest, and/or purchase

The history and philosophies pertaining to the public domain concern three outstanding measures acquisition disposal and conservation

Acquisition of Public Domain

In colonial days there were in existence two general forms of land policies (*10*) In the northern rich farm land colonies, where organized protection from Indians was essential a system of township planting was used a plot of land was divided among the colonists, who had to reside upon and improve the land allotted to them In the southern colonies, where large scale farming prevailed and where Indians were less troublesome, each settler could choose an unclaimed area of any size or shape, and in any location But the policy of land acquisition adopted in the North ultimately became nation wide

The following events chiefly account for the acquisition of the public domain lands

1783 Through cessions of state claims and by treaty with England public lands of nearly *350 000* square miles were acquired between the boundaries of the original states and the Mississippi River This acquisition clarified boundaries and administrative problems pertaining to these lands

1803 The Louisiana Purchase from France, for 15 million dollars of nearly 1 million square miles of territory, virtually doubled the area of the United States (*8*) Although the original aim of the buyers was merely to gain control of the port of New Orleans Napoleon demanded that the entire area be purchased

1819 Purchase from Spain for 5 million dollars, the territory that now is Florida This purchase was deemed administratively and strategically desirable

1846 Acquisition of Oregon Territory from Great Britain, involving more than 250,000 square miles of territory and including the states of Idaho, Oregon, and Washington This acquisition was made for strategic and administrative reasons

1848 Cession by and ultimate purchase from Mexico, for 15 million dollars, of an area in excess of 500 000 square miles embracing what is now California, Nevada, Utah, western Colorado, northern Arizona and western New Mexico The ports of San Diego and San Francisco were the chief inducements for purchase of this region

1850 Purchase from Texas for 16 million dollars of all lands then controlled by that state that lay outside its boundaries Included were southwestern Kansas eastern New Mexico part of Wyoming central Colorado and the Panhandle of Oklahoma—an area of 123 270 square miles This purchase was made to establish more satisfactory boundaries to enhance development of that region

1853 Gadsden purchase from Mexico, for 10 million dollars involving some 30 000 square miles of territory in southern Arizona and southern New Mexico This region was needed to improve boundaries and to facilitate building of rail roads in the Pacific region

1867 Purchase of Alaska from Russia for $7,200 000 involving more than 500 000 square miles Protection of the fur trade and improved national welfare justified this purchase

By these various transactions the United States secured title to 2,809,000 square miles of territory Today there remain only some 37 million acres of vacant, unappropriated, and unreserved public lands in the states outside of Federal grazing districts There are, however, 132,000,000 acres under a system of administration within Federal grazing districts

The states formed from the various acquisitions were given no title to the public lands within their borders and they had no voice in their administration Until disposed of, the public lands belonged to the nation, with Congress alone responsible for their administration or disposal (*6*)

Disposition of Public Domain

Three factors were primarily influential in the disposition of the public domain, namely disposal for revenue, disposal to encourage settlement, disposal for internal improvements

Disposal for Revenue Hamilton was the first to initiate sales of public lands to obtain revenue This practice continued until about

1840, when the Jeffersonian principle of land disposal to encourage settlement was adopted

The following chronology summarizes the main events pertaining to disposal of the public lands

Military Bounties Originally designed to favor Royalist soldiers who fought in the Revolutionary War, this measure was later adopted by the Federal government to encourage war veterans to develop the land The total acreage disposed of by this means was 68 million

Ordinance of 1785 This provided for public sale of domain lands in the Northeastern Territory, in 640-acre units, at a minimum price of $1 00 per acre The act failed of its purpose because the farm acreage was too large and funds for purchase were unavailable

Harrison Land Act of 1800 Provided for credit to purchase the lands and for reduction of units to 320 acres

Act of 1820 Discontinuance of the credit system, establishment of the minimum price of $1.25 per acre, and reduction of the minimum unit to 80 acres.

Disposal to Encourage Settlement. Legislative acts after 1820 mark the end of the era of disposal of public lands specifically to secure revenue After the period of 1820, European immigrants and citizens alike were encouraged to settle on the land

Act of 1841 This provided that preference be given to the settler over the land speculator and the squatter

Homestead Act of 1862 Termed the most workable land law of all, it provided for title to 160 acres per family after 5 years' residence, or for a shorter period upon payment of $1.25 per acre This act accomplished outstanding results in the fertile Midwest—though not without speculative hindrances—but proved unsuitable in the drier western range country where much larger acreage was needed to support a family

Timber Culture Act of 1871 This was designed to avert an impending "timber famine by providing for tree planting on one fourth of individual 160-acre units. In 1891 this act was repealed because of its virtual failure

Desert Land Act of 1877 An act adapted to arid western states, by which 640-acre units (later revised to 320 acres) could be obtained for $1.25 per acre after reclamation by irrigation This act was almost a complete failure because of unavailability of water

Enlarged Homestead Act of 1909 Concerning only the far western range states, this act provided for acquisition of 320 acres of nonirrigable land, one fourth to be cultivated This act inadvertently resulted in segregating the arid public domain into small uneconomic units and in breaking up valuable forage sod

Stock Raising Homestead Act of 1916. This applied to nonirrigable grazing lands by which 640-acre units could be homesteaded The acreage proved too small to support a family Most of the 30 million acres claimed under the act by 1933 are now owned by large stock operators

Homesteading Under Taylor Grazing Act of 1934 This act provides for filing on agricultural land up to 320 acres lying within Federally administered public land areas. Since this territory contains little farm acreage, the act is relatively unimportant

Disposal for Internal Improvements. In the interest of education and related improvements, more than 200 million acres of Federal lands were granted to the various states when they were admitted to the Union. In the West, a large proportion of these lands eventually became the property of stockmen through sales by the states.

Most conspicuous among the land grants were those made to railroads to compensate for aiding in settlement and development of the country. Because of the large outlay of funds for railroad construction, the land subsidy measure seemed justified. Generally, alternate sections of land were granted along a strip from 10 to 40 miles wide on each side of the railroad right-of-way. These railroad grants amounted to 91 million acres exclusive of revested areas. The main purpose of granting alternate sections was to stimulate uniform settlement. Such scattered land ownership, however, proved unwise: stockmen could not make a living on 640 acres, nor could railroad officials readily sell the dispersed land sections. Eventually the railroad companies sold much of this land, also they purchased or exchanged lands partly to consolidate their holdings (*1*).

Other Land Acts

Among other major land acts, though of lesser significance to the grazing industry, were the Swamp Land Act of 1849, the Free Timber Act of 1878, and the Timber and Stone Act of 1878. These acts were accompanied by much fraud and resulted in consolidation of large land holdings in private hands.

Conservation of Federal Lands

As pointed out, after the Civil War exploitation of land resources was rapid. Between 1870 and 1890 many watershed lands passed into private hands, extensive timber and grazing resources were being depleted, and soil erosion was accelerated. These conditions awakened the public, particularly in the eastern states, to the idea of conserving the remaining public domain resources. This, it was felt, could best be accomplished by retention of land ownership and skillful administration by the Federal government (*19*). The acts that primarily resulted in setting up the conservation movements are summarized below.

National Forests—Act of 1891. Under this act President Harrison set up the first forest reserve, the Yellowstone Park timberland reserve. Although small tracts containing springs and seeps, and a considerable acreage of Indian lands had been reserved earlier, the decade of the 1890's witnessed the turning point from free, unmanaged public domain

National Parks and Monuments.[3] Because of their significant features of beauty and human interest, portions of the public domain were proclaimed from time to time as national parks Starting with the declaration of the colorful Yellowstone area, there had been set aside by 1948, for the nation as a whole to enjoy without exploitation by man, a total of 23,046,147 acres of national parks, monuments, and various smaller areas, located mostly in the mountains of the western states (7) It is intended that this acreage be forever preserved in its natural state for the benefit of mankind Accordingly, there is no grazing on these lands except in a few special instances, nor are they to be logged or otherwise used commercially, instead they are reserved to give enjoyment and inspiration to the people and to provide grounds for the study of botany, ecology, geology, zoology, and other natural sciences

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[3] National parks are the superlative scenic areas set aside and conserved in their natural state in recognition of the great works of nature National monuments on the other hand, are the areas or objects of outstanding prehistoric, historic, or scientific value, set aside and conserved unimpaired because of their national interest

PART 2

NATIVE RANGE FORAGE PLANTS

Chapter 7

FORAGE PLANTS AS A BASIS OF RANGE PRODUCTION

Grazing animals, when permitted to go about freely on the range, feed cafeteria style. They select the plants that smell and taste best and may shift from one plant group to another as the season advances. Though some kinds of livestock graze a wider variety of forage than others, all consume many kinds of plants, ranging from the small, non-seedbearing forms to woody vegetation. A knowledge of what livestock feed upon and how a desirable forage cover may be maintained is essential to a successful pasture-management program.

Forage Contributions of the Different Plant Divisions

The world's present flora comprises more than a quarter of a million species, many of which serve as food for livestock, big game mammals, and other wildlife. This entire plant kingdom is grouped into four major divisions, and in this chapter we consider the extent to which these divisions contribute to the world's grazing resources.

THALLOPHYTA (ALGAE, BACTERIA, FUNGI)

The plants of this lowest and simplest plant group range in size from microscopic, single celled organisms to the largest of seaweeds, and in growth habit from parasites and saprophytes to such symbiotic organisms as lichens and algae (3). Despite their diverse characteristics the plants of this phylum contribute much directly or indirectly, to the forage or to its assimilation by grazing animals. The thallophyta are sectionally important as food plants, but man must guard himself and his animals against the toxins contained in or produced by some forms including the molds that often render damp hay and grain poisonous to stock. The blue green algae are often a nuisance in water troughs or stagnant pools, and the fungus ergot which grows on the seed heads of some range grasses is poisonous, but other fungi that produce compounds like penicillin are a salvation to mankind. Similarly, some forms of mushrooms are poisonous to man and beast, whereas others are

wholesome and nutritious. Various putrifying bacteria produce highly toxic substances, but others, notably those that break down cellulose (fiber) and pentosans in the digestive tracts of horses and ruminants, are indispensable to the nutrition of these animals. A few members of this group, like the stoneworts (*Chara*) and sea lettuce (*Ulva*), provide food for waterfowl, and the outstanding grazing species contributed by this plant division are the lichens of the far north, upon which reindeer and caribou chiefly exist during winter months.

Bryophyta (Mosses, Liverworts)

These are small leafy, often tufted plants, with short stems that bear the sex organs. *Sphagnum* moss is an example. Many structural features indicate that these plants are a link between the more primitive thallophyta and the more advanced pteridophyta. In the tundra some mosses and liverworts contribute to the reindeer forage, but on the whole this group is measurably less valuable in range livestock production than the thallophyta, although it contains fewer toxic plants.

Pteridophyta (Ferns, Club Mosses, Horsetails)

This group includes the more highly developed forms of nonflowering plants with differentiated roots, stems, and leaves. Although mostly herbaceous, they range in size from the tiniest of rooted plants to trees; they are most luxuriant and abundant in wet or moist semishaded sites. Their contribution to the forage is the lowest of the groups of nonflowering plants. Young fronds of bracken fern (*Pteridium aquilinum*) are eaten by some herbivores, particularly deer, apparently without ill results, but the plant is poisonous to domestic stock. Likewise horsetails (*Equisetum* spp.) are consumed without harm by waterfowl, notably ducks, but are poisonous to stock.

All factors considered, the Thallophyta contribute more food than the other two divisions of nonseedproducing plants.

Spermatophyta (Seed Plants)

This pre-eminently important division is distinguished from the foregoing groups by having clearly differentiated and specialized roots, stems, and leaves, by a highly developed conductive system, and by producing seed. All of the common trees, shrubs, crop plants—in short, all flowering plants—are included in this phylum. The spermatophyta are separated into two broad classes.

Class I, Gymnospermae. These plants are characterized by formation of the endosperm before fertilization takes place and by ovules

that are not borne in a closed structure. Common representatives are pines, firs, spruces, junipers, ginkgo, and jointfirs (*Ephedra* spp.), jointfirs being the most palatable of the gymnosperms. The amount of stock feed produced by this plant class is obviously small. The conifers, notably ponderosa pine, are sometimes browsed destructively by sheep and goats when other vegetation has dried up or is scarce. Western yew (*Taxus brevifolia*) is poisonous to stock.

Class II, Angiospermae. These plants usually have well developed, often showy, flowers, and ovules that are borne in a closed structure. This class comprises a vast number of seed plants and is broken down into two subclasses, the *monocotyledons* and the *dicotyledons*.

Monocotyledons are characterized by an embryo having a single cotyledon, or seed leaf, by stems with woody fibers distributed through the ground tissue rather than laid down in layers, by vascular bundles that are scattered through the stem tissue, by leaves that are typically parallel veined and linear. The flowers in one group are conspicuous with parts in threes or in multiples of three, as in lilies, orchids, and palms; in other groups the flowers are of the same general arrangement but inconspicuous, as in grasses, sedges, and rushes. Since the grass family, as discussed in the two following chapters, clearly outranks any other in its usefulness to man, the monocotyledons include by far the most important pasture and fodder plants of the major segregates of the plant kingdom. Many species are also important as food for waterfowl.

Dicotyledons are characterized by an embryo having two cotyledons, or seed leaves, by stems with woody fibers that have a layer between the pith and the bark and that increase in thickness by growing annual layers or rings, by vascular bundles so located as to form a concentric pattern, by leaves that are commonly broad, often compound, with palmate or net venation, and by flowers with parts in fours or fives or in multiples of four or five. Most deciduous trees and shrubs and broad-leaved herbs such as fireweed, cow parsnip, and geranium belong to this vast subclass of 175 families. To realize how richly the dicotyledons contribute to the pasture and hay crop, it need only be recalled that such plants as filaree, clover, alfalfa, bitterbrush, sagebrush, and willow are members of this group. Included also are most of the really troublesome stock poisoning plants of the range, such as larkspur, loco, and milkweed. The dicotyledons, however, provide a desirable variety to livestock pasturage, and many species furnish food for waterfowl and land birds. Important though the dicotyledonous plants are as food plants they rank much lower than the monocotyledons.

Evaluation of Forage Species

Since most range areas contain a mixture of plants—grasses, forbs, and shrubs—the question often arises as to the relative food value of the different forms and species. Such a complex of food plants tends to complicate grazing practices, for the various life forms do not react in the same way to grazing. Sound range management provides for the maintenance of all the more valuable forage species, including the understory herbs of browse ranges. It is important, therefore, to know which are the chief food plants, how they compare with each other in pasture value, and what the requirements of the different species are for reproduction and maintenance.

To obtain an impersonal forage value classification of the individual species, use of the following forage evaluation guide is helpful.[1] For convenience in field work, the outline can be printed or mimeographed on sheets to fit into a pocket notebook.

Preference by stock for a plant, as listed under "*D*," is not in itself of sufficient importance to give a species high forage rank. Some eagerly sought species endure but light grazing and may not occur in abundance. A first-rate forage plant should be abundant and widely distributed; reproduce well, endure at least moderate grazing, be sought by stock preferably throughout the grazing season; have a long period of succulence; and retain a high level of nutrition after maturity.

Some species are rated high as forage in some regions and mediocre in others. This may happen because the plant occurs in associations of different botanical composition. Also, in a mixed forage cover the selectivity of a plant is greatly influenced by the kind of stock grazed, such as cattle, horses, sheep, or goats, and by the native mammals occupying the range (Chapter *17*).

Importance of Grasses

Of all plants, the grasses are the most important to mankind. That "all flesh is grass" cannot be factually disputed, for man and his animals subsist largely upon plants of the grass family (*1*, *6*). The grains of barley, corn, oats, millet, rice, and wheat furnish the staple foods of mankind and are an important source of alcohol, glucose, and starch. Grasses are the most important forage for livestock and many wild animals for three reasons: they predominate over enormous areas; they are highly palatable and nutritious as pasturage and hay; and they endure grazing better than most plants (Chapter 3). They are also used in making brooms, brushes, cordage, and paper; and their essential oils are employed in perfumeries. In tropical Asia, for example, bamboo furnishes lumber for houses, bridges, and tools. Grasses are also important in protecting the soil of pasture and other lands from destructive erosion. So adaptable are they that they occupy all parts of the habitable earth. In height they vary from less than an inch, as in the far north, to more than 100 feet in the tropics, where the tallest of the bamboos form extensive forests or impenetrable jungles.

Characteristics of Grasses

Most persons speak of almost any low-growing vegetation as "grass," especially if it is grazed. To students of plants, grasses are members of a natural family, Gramineae (Poaceae), and have certain structures in common (*5*). Grasses are herbs (in temperate regions), with fibrous roots and jointed culms (stems), mostly hollow (rarely pithy) except at the solid nodes. The culms are simple (nonbranching), or they may bear branches at the nodes (Fig. *31*). There are some 6000

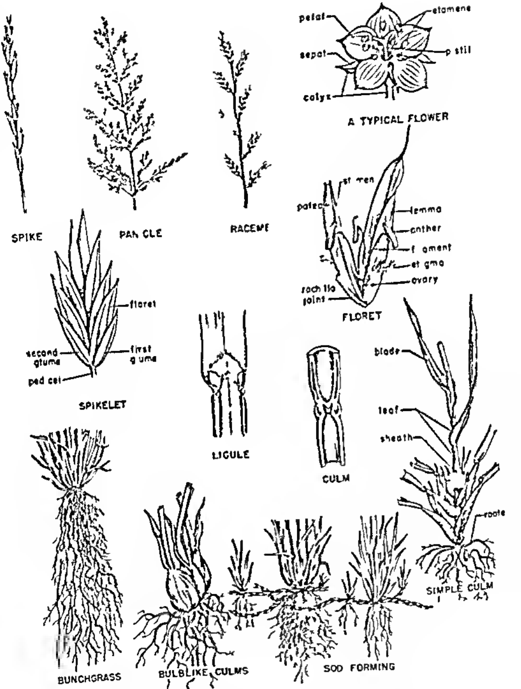


Fig 31 Floral and vegetal diagram of grasses The parts of a common flowering nongrasslike plant is shown for comparison with the more primitive typical floret of a grass

species of grasses, more than in any other family of flowering plants except the orchid, the sunflower, and the pea families

Leaves

The leaves are borne one at each node, always in two ranks They are parallel-veined and composed of two parts the *sheath*, which surrounds the culm like a split tube, and the *blade*, which is usually strap-shaped At the junction of the sheath and the blade, on the inside, is a small appendage, the *ligule* (Fig 31)

Flowers

The flowers are small, composed of a single ovary with two styles (one in corn) bearing feathery stigmas, and three stamens, rarely one or six (Compare the grass flower with the complete flower in Fig 31) The ovary contains an ovule that, when fertilized, develops into the caryopsis (seed), the stamen consists of a two-celled anther borne on a slender filament Each flower is borne in the axil of a small green bract, the *lemma*, and is enveloped in a smaller inner bract, the *palea* The flower, with its lemma and palea, is termed the *floret* The florets, like the leaves, are borne in two ranks upon a small axis, the *rachilla* Below the florets are two bracts without flowers, the *glumes* The glumes, rachilla, and florets are collectively termed the spikelet (Fig 31)

Inflorescence

In oatgrasses, bromes, and bluegrasses the spikelets are on pedicels (short stems) on the branches of a *panicle* In some grasses, such as timothy and millet, the panicle branches and the pedicels are so short that the inflorescence more nearly resembles a spike In wheatgrasses and in the wild-ryes the spikelets are sessile (without a pedicel), on opposite sides of a simple axis but at different nodes, forming a *spike* Somewhat intermediate between a panicle and a spike is a type of inflorescence in which the flowers are borne along an axis on short pedicels of nearly equal length, forming a *raceme* (Fig 31)

Length of Life

Grasses may be annuals, completing their life cycles in a single season, as in many bromes, or perennials, the individual plants living from 2 to several years and seeding year after year, as in Idaho fescue Perennial grasses, besides producing seed, increase vegetatively (Chapter 3)

Outline of the More Important Grass Tribes

The following illustrated outline shows the form of inflorescence or head and the characteristic spikelet of each of the eight tribes that embrace the more important forage grasses

SERIES I FESTUCOIDEAE

Spikelets laterally compressed, florets mostly falling from persistent glumes

A Oat Tribe (Aveneae)

Like fescue tribe, but glumes enlarged and florets fewer, lemmas awned from the back (not developed in *Koeleria*) (Wild oats, Junegrass, trisetums, hairgrasses)

B Barley Tribe (Hordeae)

Spikelets 1- to many-flowered, sessile on opposite sides of a jointed rachis, forming a spike rachis rather than spikelets specialized inflorescence a solitary spike (Wheat and wheat grasses, barley and barleygrasses, rye and ryegrasses)

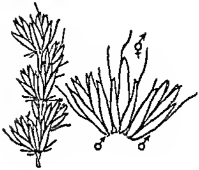
C Fescue Tribe (Festuceae)

Spikelets few to several flowered laterally compressed, florets falling from the glumes, glumes relatively small, lemmas awned from the tip or just below it, inflorescence an open or narrow panicle (Bromes fescues, melicgrasses, bluegrasses.)

D Grama Tribe (Chlorideae)

Spikelets 1- to few flowered, sessile on one side of the rachis, all but the lowest floret commonly sterile and variously modified, inflorescence of 1 to many 1 sided spikes, spaced along a main axis or clustered at its summit (Buffalo grass, gramas, chloris grass)

E Mesquite Tribe (Zoysieae)



Spikelets 3 together, 1 perfect and 2 staminate, sessile and appressed to the axis forming a spike, the 3 falling together, attached to each other (Mesquite grasses)

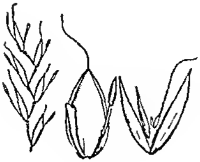
F Timothy Tribe (Agrostideae)

Like Festuceae reduced to its lowest terms, spikelets 1 flowered, lemmas awnless or awned the awn from back or summit, inflorescence an open or narrow panicle (Needlegrasses, redtops reedgrasses timothy)

Series II Panicoideae

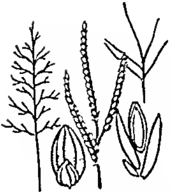
Spikelets dorsally compressed falling entire, singly or together with joints of the rachis

G Sorghum Tribe (Andropogoneae)



Spikelets paired 1 perfect and sessile, the other sterile and pediceled borne on a jointed rachis Fertile spikelets with 1 perfect terminal floret and a sterile lemma below, falling with joints rachis and sterile pediceled spikelet attached Glumes hardened inclosing the florets (Beard grasses, Johnson grass sorghums)

H Millet Tribe (Paniceae)



Spikelets with 1 perfect terminal floret and a sterile floret below, rachilla joints very short, glumes membranaceous, the first small, suppressed in some genera, sterile lemma like the second glume, fertile lemma and palea hardened (Carpet grass, Dallis grass, millets)

Key to the More Common Tribes and Genera

The following key is essentially applicable to the semiarid and range area west of the 100th meridian Use the key by reading contrasting paragraphs (1*a*, 1*b*, 2*a*, 2*b*, etc.) and choosing the one with which the grass at hand agrees Follow the key until it leads to a name, and compare the specimen with the generic description in the subsequent discussion of the tribe in this or the following chapter.

3b Glumes as long as lowest floret, usually longer, lemmas awnless or awned from back (except *Danthonia*) OAT TRIBE (Aveneae)
Spikelets over 12 mm long
Florets 2 or 3, lemmas awned from back *Avena*
Florets several, awn from bifid apex of lemma *Danthonia*
Spikelets not over 12 mm long
Lemmas awnless or with a minute awn just below apex *Koeleria*
Lemmas awned from back
Lemmas keeled, 2-toothed at apex, awn arising from above the middle *Trisetum*
Lemmas rounded on back, jagged at summit, awn arising from below the middle *Deschampsia*
2b Spikelets with 1 perfect floret, a sterile lemma below in some genera
4a Spikelets all alike, glumes not firmer in texture than the lemmas
5a Spikelets with sterile lemma below the fertile floret, fertile lemma and palea hard in texture, dorsally compressed
MILLET TRIBE (Paniceae)
Spikelets subsessile, in one sided racemes, first glume wanting
Spikelets solitary nearly oblong, not plano convex, blades obtuse or nearly so *Axonopus*
Spikelets mostly paired, ovate or obovate, plano-convex, blades acute *Paspalum*
Spikelets in panicles, first glume present *Panicum*
5b Spikelet with no sterile lemma, spikelets (at least glumes) laterally compressed TIMOTHY TRIBE (Agrostideae)
6a Lemmas hard at maturity, awned at summit, sharp pointed at base
Awn simple (not divided), a distinct line between the awn and body of the lemma
Awn 24–70 mm long, persistent *Stipa*
Awn about 6 mm long, falling off at maturity *Oryzopsis*
Awn 3 divided, no line between awn and body of lemma *Aristida*
6b Lemmas not hardened, not sharp pointed at base
7a Glumes longer than floret
Spikelets V-shaped or nearly so
Florets naked or nearly so at the base, palea small or wanting *Agrostis*
Florets with a tuft of soft hairs at the base, palea prominent, rachilla produced beyond base of palea, hairy *Calamagrostis*
Spikelets 2-horned, each glume awned from an obtuse or square summit, panicles dense, spikelike *Phleum*
7b Glumes usually shorter than floret, mostly equal
Lemmas 1-nerved, awnless *Sporobolus*
Lemmas 3-nerved, mostly awned or mucronate *Muhlenbergia*
4b. Spikelets of 2 kinds perfect and staminate or sterile, the two paired in jointed racemes, glumes firmer than the floret
SORGHUM TRIBE (Andropogoneae)
Racemes of several to many joints 1 to few on each peduncle, the joints and pedicels hairy *Andropogon*

Racemes of 1 or few joints numerous, borne in a compound panicle
Perfect spikelet rather turgid pedicellate spikelet staminate, panicle not conspicuously hairy *Sorghum*
Perfect spikelet *not turgid* pedicellate spikelet wanting, panicle conspicuously hairy bronze *Sorghastrum*

1*b* Spikelets sessile on the rachis forming spikes
8*a* Spikelets not falling entire from the rachis, the florets falling from the glumes or rachis disjointing with spikelets attached
9*a* Spikelets large, on opposite sides of the rachis, spike single BARLEY TRIBE (Hordeae)
Rachis of spike not breaking up, the florets falling from the glumes at maturity
Spikelets single at each node of the rachis
Spikelets placed flatwise to the rachis, both glumes present *Agropyron*
Spikelets placed edgewise to the rachis, first glume wanting, except on terminal spikelet *Lolium*
Spikelets 2 at the nodes (occasionally 1 to 4) *Elymus*
Rachis of spike breaking up at maturity, spikes bristly
Spikelets 3 at the node, the lateral ones pediceled and sterile *Hordeum*
Spikelets 2 at the node, glumes sometimes cleft *Sitanion*
9*b* Spikelets small, on one side of the rachis spikes one-sided small, 1 to many GRAMA TRIBE (Chlorideae)
Spikes *racemose along the axis*
Spikes all alike, flowers perfect *Bouteloua*
Spikes different, flowers unisexual, in distinct spikes, pistillate in small subglobose heads *Buchloe*
Spikes clustered at the summit like stocks of a fan, digitate *Chloris*
8*b* Spikelets falling entire in clusters of 3, 1 perfect and 2 staminate subsessile on opposite sides of the rachis MESQUITE GRASS TRIBE (Zoysieae)
(*Hilaria is the only important forage genus of this tribe*)

Practically all the highly valuable, native forage grasses of the United States belong to eight of the total of fourteen existing tribes or subfamilies The species of six of these tribes comprise most of the forage grass stand on the western range, hence these are discussed more fully than the other two A few species mentioned are naturalized exotics

Some Suggestions in the Study of Grasses

With a sincere spirit of helpfulness to the young instructor of range management, the author presents an outline of procedure that has proved satisfactory in teaching the study of range grasses

The study covers one weekly 3-hour laboratory period through a semester of 16 weeks The first two periods are devoted to orientation and review, and are conducted as follows

Period one is spent in the study of germinating seeds of corn, wheat, and bromes which had been placed in a germinator 2, 4, and 6 days,

respectively, before the first laboratory period The student makes free-hand, longitudinal sections of these sprouting seeds, studies their structure, and compares them with a chart that illustrates the structure of a cereal grain in longitudinal section, stressing such parts as are shown in Fig 32 Also in this first period, the student sketches micro-

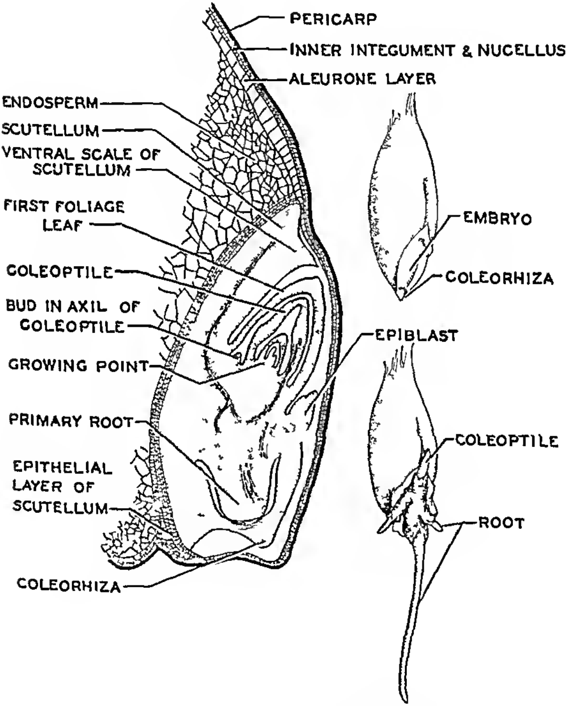


FIG 32 Longitudinal section of a wheat seed showing its different features The sketch typifies grass seeds generally Two stages of seed germination are shown on the right

scopic longitudinal sections of grass leaf buds from permanently mounted slides

In period two the gross morphology of grasses is considered. Generalized *forms of roots* are studied first, including rhizomes and stolons, also intravaginal and extravaginal structures, next the *aerial framework* such as the culm, sheath, blade, and ligule, then the *inflorescence*, embracing the spike, panicle, raceme, and spikelet, with particular attention to the rachis, glumes, lemmas, palea, rachilla, stamens, and pistils, and including unisexual structures. Genera with large structures are used, as in species of *Avena*, *Agropyron*, *Bromus*, and *Lolium*.

Actual grass identification work starts in the third laboratory period, with the oat tribe (Aveneae), species with large, open panicles being selected first. The third and fourth periods are taken up by the rather detailed study of the forage species of this tribe. Then the class is introduced to the barley tribe (Hordeae), thus becoming familiar with spiked inflorescences, and solitary or paired spikelets. Acquaintance with the characters of the two contrasting oat and barley tribes seems basic to the recognition of the intermediary and other structures encountered in the eight tribes embracing the grasses studied later and discussed in Chapters 8 and 9. The periods after that are devoted to concurrent studies of the tribes, genera, and species, using Hitchcock's *Manual* (4) or an authoritative local flora. After the initial laboratory period, the first minutes of each laboratory session are devoted to a written quiz covering essentially the readings and the laboratory assignments of the previous week. The questions are graded immediately, first by the students themselves (each exchanging his paper with his neighbor) as the answers are orally and informally discussed between instructor and student. After that, the papers are collected for final grading and recording by the instructor. In addition, three or four full laboratory periods are reserved for formal examinations of "unknowns", that is, the identification of species not studied before but belonging to tribes previously worked with. Twenty five percent of the semester's grade is allowed for the quizzes and the rest for identification of unknowns.

Throughout the semester, and particularly during the first few periods, the useful primer, the ***First Book of Grasses***, by Chase (*1*), is closely studied, and its sketches compared with the material at hand. The economics of the species studied is considered in appropriate weekly assignments in the ***Range Plant Handbook*** (2) and similar publications.

The student will have need for a hand lens of about 10 diameters and for a dissecting set.

Literature Cited

1 CHASE, A 1937 *First Book of Grasses* Published by W A Silveus, 832 Cambridge Oval, San Antonio, Texas 125 pp
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3 HILL, J B, L O OVERSHOLTS, AND H W POPP *1936 Botany* McGraw-Hill Book Co Inc, New York 672 pp
4 HITCHCOCK, A S 1935 Manual of the Grasses of the United States" *U S Dept Agr Misc Pub* 200 2nd ed, revised by Agnes Chase pp 1–1051
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6 U S Department of Agriculture 1948 *Grass 1948 Yearbook of Agriculture* 892 pp

Chapter 8

DISCUSSION OF THREE TRIBES OF RANGE GRASSES

Oat Tribe (Aveneae)

Members of the tribe Aveneae have spikelets (*5*)[1] of 2 to several flowers, glumes that are usually longer than the first lemma—which is papery in texture and shining, lemmas that are usually awned on the back or from between the teeth of the 2-cleft tip, the awns generally being bent or twisted, and the callus, which, with the rachilla joints are often hairy. This tribe contains some 40 genera, 11 of which are represented in the United States. It includes cultivated oat, also the domesticated hay and forage plant, tall meadow oatgrass, and a few broadly useful native pasture species such as wild oat,[2] hairgrass, Junegrass, trisetum, and the oatgrasses (*19, 21*).

Oats (*Avena*)

These are robust annual grasses (the 2 native perennials are too scarce to be important) with flat leaves and large, loose panicles, the spikelets having 1, 2, or sometimes several florets. The lemma is rounded on the back and bears a long, usually bent or twisted, dorsal awn and an oblong, deeply furrowed grain enclosed in the palea. Only 2 of the 55 species are native to North America but several European forms are well established in this country (*14*). The most important forage species are wild oat and slender wild oat.

[1] References cited in this chapter are listed at the end of Chapter 9.

[2] The following publications have been especially consulted in this treatise: *First Book of Grasses*, by Chase (*4*); *Range Plant Handbook*, by Dayton and associates (*6*); *Manual of the Grasses of the United States*, by Hitchcock (*11*); *Native American Forage Plants*, by Sampson (*23*); *Range Grasses of California* by Sampson, Chase and Hedrick (*24*), and a few other state and Federal bulletins. The common names of the grasses discussed here are mostly taken from Hitchcock's *Manual*, Dayton's *Handbook*, or from *Standardized Plant Names* by Kelsey and Dayton (*15*).

1[3] Wild Oat[4] (*A. fatua*). This tall, erect, pale-green annual resembles cultivated oat but differs in having longer panicles, denser, stiff, brown hairs on the lower part of the lemma, a long, twisted awn, and a smaller grain (Fig. 33*A*). Wild oat, introduced from Europe, grows at medium elevations throughout the United States except in the Southeast. Exceptionally dense stands frequently occur in the foothills of California. It has about the same forage value as cultivated oat and is most palatable and nutritious when green (*9*). It matures early in the summer. Heavy stands are sometimes cut for hay. The general forage rating is "good."[5]

2. Slender Wild Oat (*A. barbata*). This species is similar in appearance to wild oat but has more slender culms, narrower panicles, and lemmas that end in 2 long, slender teeth. Economic production of slender oat is confined to the Pacific Coast states. Like wild oat, it is closely grazed when young. If cut before maturity it produces good hay. Because of restricted distribution its over-all rating is listed here as "fair."

Haircrasses (*Deschampsia*)

These are annual and perennial grasses with narrow leaves and mostly loose, shining panicles, spikelets with 2 perfect flowers, the lemmas 4-nerved, 2- to 4-toothed, and bearing a small awn below the middle of the back. Of some 40 species of hairgrasses, 6 occur in the western United States. Tufted hairgrass is the most important species (*23, 24*).

3. Tufted Hairgrass (*D. caespitosa*). This perennial bunchgrass grows 2–4 feet tall, and has smooth culms and numerous, mostly basal leaves. The panicle is 4–8 inches long, bearing small shining spikelets, the lemmas being notched at the tip and having a short awn on the back (Fig. 33*B*). It occupies bogs and wet places from Greenland to Alaska, south to New Jersey, West Virginia, Illinois, North Dakota, New Mexico and California.[6] On mountain meadows and bottom lands

[3] For convenience in assigning class readings or in referring to specific grasses the species discussed in this and the following chapter are listed numerically.

[4] The name "wild oat" is here restricted to uncultivated forms of *Avena*, the name "oatgrass" to species of *Danthonia*, both belong to the tribe Aveneae.

[5] The general forage rating of excellent, good, fair, or poor, as given at the end of the discussion of each species is based upon distribution, abundance, livestock preference, and nutrition. Although the grazing value of some species varies somewhat in different regions and plant associations, the single over-all forage rating given should be helpful to the beginner in remembering grazing values.

[6] Distribution of a species is generally described by giving outer limits of its occurrence.

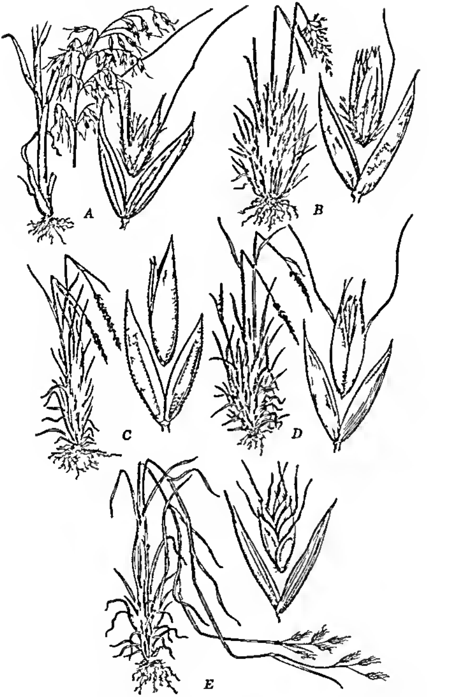


Fig. 33 *A* Wild oat (*Avena fatua*) *B* tufted hairgrass (*Deschampsia caespitosa*) *C* Junegrass (*Koeleria cristata*) *D* spike trisetum (*Trisetum spicatum*) and *E* California oatgrass (*Danthonia californica*)

in many parts of the West it often composes most of the stand. When succulent, tufted hairgrass is sought by all kinds of stock; it withstands grazing and trampling well. The denser stands are sometimes cut for hay. Its forage rating is "good."

JUNEGRASSES (*Koeleria*)

These erect perennial grasses (the annuals are rare) are densely tufted and have flat or rolled leaves. The panicle is narrow, mostly spikelike, pale, and shining, the spikelets having 2 to 4 florets which are awnless or short-awned; glumes are of unequal length, somewhat shorter than the spikelets, greenish, with papery margins. About 20 species of Junegrass occur in the temperate regions of both hemispheres, but only 1 species is important as forage.

4. Junegrass (*K. cristata*). This tufted perennial grows 1–2 feet tall and has culms that are minutely hairy just below the panicle. The leaves are mostly basal, flat or slightly rolled, smooth or rough in texture, and sometimes downy; the shiny panicle is pale-green and spikelike (Fig. 33C). It occurs on well-drained soils from Ontario to British Columbia, south to Pennsylvania, Oklahoma, and west to the coast of California, up to about 11,000 feet in elevation. While green, the entire plant is eaten by all kinds of stock, but as maturity approaches only the tender leaves are consumed. The yield of forage per plant is not especially large. The over-all forage rating is "good."

TRISETUMS (*Trisetum*)

These tufted perennial, or rarely annual, grasses have flat leaves, a dense or loose panicle, and spikelets of 2 to 4 perfect flowers, the uppermost staminate. The glumes are unequal and keeled, the lemmas are papery, usually shorter than the glumes, keeled, and 2-toothed at the tip, each bearing above the middle of the back a slender, bent, and twisted awn. There are about 65 species of *Trisetum*, 10 occurring in the United States. Only 1 species is important on the range.

5. Spike Trisetum (*T. spicatum*). This perennial bunchgrass has culms 1–2 feet tall, of a silvery to white cast, and sheaths that are smooth or velvety. The panicle is dense, spikelike, cylindrical, and shining, and the lemmas bear a dorsal, slender, divergent awn (Fig. 33D). It occurs in Arctic America and in all the western states, where it occupies open, moist, alpine and subalpine sites, mostly between 5000 and 12,000 feet in elevation.

Although spike trisetum grows only in scattered stands and has rather weak seed habits, it supplies considerable forage of good quality (21).

Its palatability varies widely in different regions, it is high in the Northwest and in California especially for cattle and sheep, and fair to good in the Rocky Mountains The over-all forage rating is 'good

OATGRASSES (*Danthonia*)

These leafy perennial bunchgrasses have spikelets containing several florets, glumes longer than the lemmas and commonly as long as the spikelets, 2 toothed lemmas that bear from between the teeth a strong flat, twisted, and bent awn There are about *100* species of *Danthonia*, and 6 of the 7 that occur in North America are found in the West California oatgrass and timber oatgrass are the most important forage species

6 California Oatgrass (*D californica*) This species grows 2–3 feet tall and produces abundant, smooth, basal leafage The spreading panicles bear 3 to 4 spikelets, each about ¾ inch long (Fig 33*E*) It ranges from British Columbia to Montana, Colorado, and California occupying both dry and moist soils of hillsides mesas, and canyons of the ponderosa pine aspen, and spruce belts The leafage is highly relished by cattle and horses and is fairly palatable to sheep It endures grazing rather well The general rating is "good'

7 Timber Oatgrass (*D intermedia*) This species differs from California oatgrass by the shallow roots, the narrower panicles, and the purplish spikelets It ranges from Quebec to British Columbia, California, and New Mexico, chiefly in the spruce and alpine belts, but often extends downward to the ponderosa pine and oak brush covers The abundant basal leafage is grazed closely up to maturity by all kinds of stock in the Northwest, Montana, and Utah, in some localities it is not grazed avidly Its general forage rating is good'

Barley Tribe (Hordeae)

The grasses of this tribe have heads of a solitary, symmetrical spike (not one sided) sessile spikelets of 1 to several florets on opposite sides of a jointed or a continuous rachis and lemmas that are usually awned Although the tribe embraces only about 200 species within 12 genera, it includes many highly important pasture grasses as well as the cereals of wheat, barley, and rye, the cultivated ryegrasses (*Lolium* spp), and crested wheatgrass (*Agropyron cristatum*) (*2*) The wheatgrasses and wild ryes embrace the most important forage species of the tribe The barley grasses and squirreltail grasses are sometimes locally abundant on the range, but many of their species are mechanically injurious to livestock, hence they are of relatively low forage rank (*20*)

WHEATGRASSES (*Agropyron*)

These are perennial bunchgrasses or sodformers, they have flat or rolled leaves, and spikelets that are solitary at the nodes and placed flatwise to the rachis In many parts of the Northwest and the Rocky Mountain region the wheatgrasses constitute the most important forage species Because they require a long rest period of cold winter weather, their occurrence in areas of mild climate is limited There are about 35 species of wheatgrasses in North America, 23 occurring in the western states with Colorado the center of distribution. The forage of wheatgrasses is eagerly sought by all kinds of stock Because of the coarse culms, these grasses are best utilized by cattle and horses and are grazed with good results throughout the year In spring and winter the leafage is also excellent for sheep In the Northwest, the northern and central Great Plains, and the Inland Empire, the wheatgrasses are of inestimable value for hay and winter grazing The species are high in succession, constituting the climax herbaceous cover over large areas (*22*) Some are alkali tolerant, others grow on dry, thin soils Bluebunch wheatgrass, slender wheatgrass, and bearded wheatgrass are the best of the tufted wheatgrasses, and western wheatgrass and thickspike wheatgrass are the choicest of the sodformers (*18*) Crested wheatgrass is the most valuable of the introduced pasture wheatgrasses

8 Bluebunch Wheatgrass (*A spicatum*) This bluish-stemmed, perennial bunchgrass grows 1–4 feet tall and produces numerous, smooth, flat or rolled leaves The spike is slender, 2–4 inches long, with 4 to 12 flattened, narrow spikelets, smooth, sharp-pointed glumes, and lemmas that are smooth on the back below, are 5-nerved, and terminate in a stout, twisted, spreading awn about ⅜ inch long (Fig 34*A*) This widely distributed species occurs from northern Michigan and central Alberta to Alaska, south to western South Dakota, New Mexico, and California The altitudinal range is up to 10,000 feet It is often the chief grass on rocky areas, dry, open woods, plains, and benchlands The forage is eagerly sought by all kinds of stock at all seasons The forage rank is "excellent"

9 Slender Wheatgrass (*A trachycaulum*) This densely tufted, blue-green grass grows 1½–4 feet tall and has narrow, smooth leaf blades The spikes are slender, 2–7 inches long, the spikelets are long, narrow, 3- to 5-flowered, with rather broad glumes and lemmas that are usually tipped with a stiff, straight awn about ¼ inch long (Fig 34*B*) This is probably the most widely distributed species of

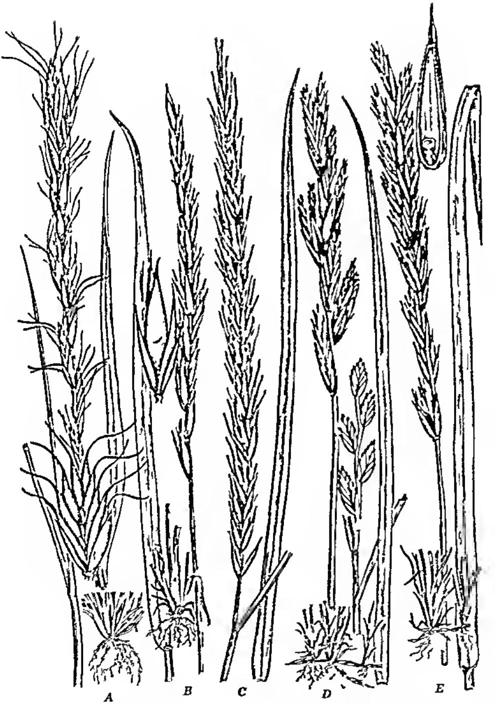


Fig 34 *A*, Bluebunch wheatgrass (*Agropyron spicatum*), *B*, slender wheat grass (*A trachycaulum*) C, bearded wheatgrass (*A subsecundum*) D western wheatgrass (*A smithii*) and *E*, quackgrass (*A repens*)

our wheatgrasses and occurs from Labrador to Alaska, south to the mountains of Virginia, Missouri, New Mexico, and California. In the West it occurs up to 10,000 feet. Slender wheatgrass grows best on well-drained, light, sandy soils and is fairly tolerant of alkali. It provides choice forage for all kinds of livestock and is sought by sheep, cattle, and horses from early spring to the end of the grazing season. The seed heads are highly palatable. The forage rank is "excellent."

10. Bearded Wheatgrass (*A. subsecundum*). This perennial bunchgrass resembles slender wheatgrass. It is 2–4 feet tall and has smooth stems and broad leaves. The nodding spike is 3–8 inches long and, by a twisting of the rachis, somewhat one-sided; the spikelets are 3- to 6-flowered, with glumes as long as the spikelets tipped with a short awn, the lemmas bearing an awn about twice their length (Fig. 34C). It is widely distributed from Greenland to Alaska, California, and North Carolina. The species is confined chiefly to fairly moist, light sandy bottom lands and meadows at medium elevations, where it forms moderately dense stands. A good cover seldom occurs above elevations of 7000 feet. The herbage is sought by all classes of stock, but because of the harsh awns at maturity, it is eaten most readily early in the season. The general forage rating is "good."

11. Western Wheatgrass (*A. smithii*). Also called bluestem wheatgrass, this valuable species is recognized by its blue green color, the creeping rootstocks, and leaves that are rigid, smooth, or slightly rough underneath. Its spikes are almost awnless, 2–7 inches long, its spikelets flattened and spreading, with 7 to 13 florets, the glumes about half as long as the spikelets. Spikelets and lemmas usually have a short awn (Fig. 34D). Western wheatgrass is among the most widely distributed of the wheatgrasses; it occurs from New York, Michigan, and Ohio to Alberta and Washington, south to Texas, Arizona, and northeastern California, mostly introduced east of Iowa and Kansas. It occupies a variety of soils, including alkaline areas, up to 10,000 feet in elevation. Few species are better for hay and pasturage, since all kinds of stock take it eagerly throughout the growing season and winter. Reproduction both by creeping rootstocks and seed is strong. Pure stands occur commonly on heavy soils of the northern Great Plains. In recent years western wheatgrass has been seeded with some success on depleted ranges and on dry farm areas of the Great Plains. The general forage rank is "excellent."

12. Thickspike Wheatgrass (*A. dasystachyum*). This sodforming grass has extensive creeping rootstocks, narrow leaves 2–10 inches long, mostly inrolling, rough, erect spikes about 7 inches long, and spikelets 8-flowered, the lemmas hairy or rough. Its range is from

Hudson Bay to Alaska, northeastern California, southern Colorado, Nebraska, and the shores of Lakes Superior, Michigan, and Huron Sandy soils produce the best cover In Utah good stands are produced up to 10 000 feet in elevation When green, thickspike wheatgrass supplies fair forage for all kinds of stock, but as mature herbage it is of low palatability Well established stands endure heavy grazing better than most wheatgrasses (*6*) The general rating is "fair"

13 Quackgrass (*A repens*) Quackgrass simulates western wheatgrass in appearance but lacks the bluish cast Also, it has lax, soft foliage and yellow-green rootstocks (Fig 34*E*) This species, introduced from Eurasia, is a weed in many localities because of its persistent rhizomes, however, in mountain meadows, quackgrass produces desirable forage The over-all forage rank is "fair"

Wild-Ryes (*Elymus*)

These are tall, somewhat coarse perennial grasses, with rough leaves and dense terminal spikes, spikelets of 2 to 6 florets borne mostly in pairs in alternate notches of the rachis, glumes nearly equal, narrow, pointed, or awned, and lemmas with a rounded back, pointed or awned, the palea being shorter than the lemma Of about 45 species of wild rye 21 occur in the United States, with Idaho as the center of distribution for the more important forms The forage rank of most of the species is intermediate Generally the leafage is harsh and coarse, and the awns of some forms are troublesome A few species such as Virginia wild rye (*E virginicus*)—abundant east of the 100th meridian—is used limitedly to stabilize the soil and is a fairly palatable plant Medusa head (*E caput medusae*), an introduced annual, is a range pest in the Pacific Coast states The most important forage species are blue wild rye, giant wild rye, beardless wild rye, and Canada wild rye These are bunchgrasses except beardless wild rye and Canada wild-rye (*8*, *26*, *29*) Some species, notably Canada wild rye and giant wild rye, are susceptible to infestation by ergot (*Claviceps* spp), a poisonous fungus (*17*, *25*)

14 Blue Wild-rye (*E glaucus*) This highly variable, blue-green perennial bunchgrass grows 2–4 feet tall, has smooth sheaths and leaf blades, spikes 2–6 inches long, numerous spikelets with 3 to 6 florets, narrow, sharp-pointed glumes, and lemmas that bear a straight, rough awn, ¼–½ inch long (Fig 35*A*) The distribution is from Ontario and Michigan to southern Alaska, south through South Dakota and Colorado to New Mexico and California In elevation it ranges as high as 9000 feet. It is the most common wild rye found on moderately moist, rich soils Early in the season the forage is taken by all kinds

of livestock; but the bearded seed heads are not eaten, and the leafage becomes harsh and unpalatable upon maturity. It has strong seed habits and reproduces well under conservative use. The general forage value is "fair."

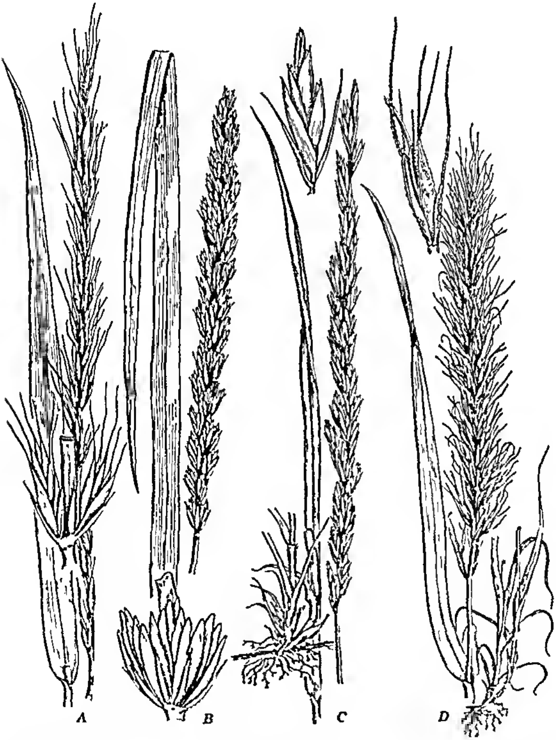


FIG. 35. *A*, Blue wild-rye (*Elymus glaucus*); *B*, giant wild-rye (*E. condensatus*), C, beardless wild-rye (*E. triticoides*), and *D*, Canada wild-rye (*E. canadensis*).

15 Giant Wild-rye (*L condensatus*) The culms of this largest of the native ryegrasses grow up to 12 feet high and ½ inch thick The dense spikes are 6–12 inches long, sometimes compound at the base, the spikelets being 3 to 6 flowered and the glumes and lemmas awn-pointed (Fig 35*B*) Giant wild rye ranges from southwestern Manitoba, west to the coast of British Columbia south to California, Colorado, and New Mexico (*11*) and from sea level to 5000 feet in elevation The typical habitat is that of fairly moist, rich bottom lands, river banks, and wet, saline areas The succulent herbage is grazed somewhat closely by cattle and horses, only limitedly by sheep The mature herbage is fibrous and harsh but, when well cured, provides winter feed of some value It is sometimes cut for hay The forage value rates as "fair"

16 Beardless Wild-rye (*I triticoides*) This species looks like a reduced form of giant wild-rye but is distinguished by having strong, creeping rhizomes (Fig 35*C*) Its range is from Montana to Washington, south to western Texas and California, up to 10,000 feet in elevation The most extensive stands occur on alkali flats and open woodlands in Oregon and Washington The young leafage is grazed rather closely by horses and cattle and to a limited extent by sheep The denser stands are frequently cut for hay A fungus, ergot, occasionally attacks the seed heads seriously The general forage value is "fair"

17 Canada Wild-rye (*E canadensis*) This stout, smooth, perennial bunchgrass grows 2–6 feet tall and has broad, flat leaves 6–12 inches long The spike is usually nodding, 4–10 inches long, the spikelets 3 to 5 flowered the glumes and lemmas tapering to stout spreading awns about 1 inch long (Fig 35*D*) This species is widely distributed in Canada and the United States is fairly abundant in most states, and is particularly important in the Great Plains region The forage is most sought by horses and cattle but to some extent also by sheep Early in the season the herbage is closely grazed, but it is only lightly cropped when mature The prominent awns are objectionable The general forage rating is "fair"

BARLEYGRASSES (*Hordeum*)

These coarse annual or perennial grasses are distinguished by their dense spikes and by the 3 spikelets at each node of the rachis, the lateral pair on short stalks, usually reduced to awns Nine of the twenty species of barleygrass are found in the United States The awns and sharp pointed rachis joints of most species are injurious to livestock, particularly sheep, they work into the skin, eyes, gums,

between the teeth, and into the throat (*1, 24*) The most common species are foxtail barley, bobtail barley, mouse barley, and meadow barley.

18. **Foxtail Barley** (*H jubatum*) This tufted perennial is the worst among the mechanically injurious grasses of the West It grows 8–30 inches tall, has rough leaf blades, and nodding spikes up to 4 inches long The rachis, which breaks up at maturity, has sharp-pointed joints that bear 3 spikelets at each node, 1 fertile and 2 sterile, all of these having long, fine, widely spreading awns (Fig 36*A*) Originally indigenous to the western states, foxtail barley now occurs from Labrador to Alaska, south to Maryland, Illinois, Missouri, Texas, and California It is a common plant on the plains and lower foothills on moist, saline, and fairly dry soils It is often a serious pest in grain and hay fields and on pastures When young and until the heads develop, foxtail barley is palatable to all kinds of livestock, but after the heads have matured the herbage is little grazed until autumn rains soften the awns and prevent injury to stock Where it grows abundantly, sheepmen aim to market the lambs before the seed heads become troublesome and then remove the ewes to clean pasture Hay containing much foxtail barley may be spread out in the rain or sprinkled artificially well before feeding time, thereby softening the awns (*24, 25*) The over all forage rating is "fair"

19. **Bobtail Barley** (*H jubatum* var *caespitosum*) This mechanically injurious form has shorter awns than foxtail barley Its palatability, usefulness, and injurious qualities are about the same as those of foxtail barley Its range is from North Dakota to Alaska, and south to Kansas and Arizona The forage rank is "fair"

20 **Mouse Barley** (*H leporinum*) Until recently known as *H murinum*, this annual grass, naturalized from Europe, is the most common of the group It is recognized by the flattish heads, 1 inch wide, and also by the awns which are 1–1½ inches long (Fig 36*B*). It occupies moist areas and open ground from the north Pacific coast, Idaho, and British Columbia, south to Utah, New Mexico, and California and appears intermittently in the eastern states Up to the time of heading, mouse barley is rather closely grazed by all kinds of stock but is grazed only moderately thereafter Its over-all forage rating is "fair"

21. **Meadow Barley** (*H brachyantherum*) This perennial bunchgrass (to which the name *H nodosum* has been misapplied) has scant foliage and short awns and is the only common species of the genus *Hordeum* that causes no annoyance to livestock (Fig 36*C*) It occupies moist areas and open ground from Montana to Alaska, south to

FIG. 36 *A*, Foxtail barley (*Hordeum jubatum*), *B*, mouse barley (*H leporinum*), *C*, meadow barley (*H brachyantherum*), and *D*, squirreltail (*Sitanion hystrix*)

New Mexico and California and occurs in some localities in the eastern states, it is also widely dispersed in the Old World Up to the time of heading, meadow barley is rather closely grazed by all stock but is grazed only moderately thereafter Although its forage rank is only "fair," meadow barley probably has the highest value of the group

Squirreltails (*Sitanion*)

This is a small, endemic genus of perennial bunchgrasses, with flat or rolled leaves, dense spikes, 2 spikelets at each node of the disjointing rachis, and glumes and lemmas that extend into long, usually robust, often cleft awns There are but 3 species of squirreltail in the western states, principally within the Great Basin area where they occupy dry, sandy, or loamy soils The awns together with the sharp-pointed rachis joints of most species are injurious to stock, hence they may be safely grazed only early in the season The forage value of the species of *Sitanion* is intermediate to low, especially after the seed heads have formed and before rains soften the awns

22 Squirreltail (*Sitanion hystrix*) This is the most common and widespread of the genus, occurring from Washington to South Dakota, Missouri, Kansas, Texas, and California As a range plant it is typical of the other species, its palatability varying according to locality and season (Fig 36*D*) Although cropped with other forage, it is of only moderate grazing value, since at maturity the awns are likely to cause annoyance to livestock (*16*) The general forage rank is "fair"

Fescue Tribe (Festuceae)

The culms of grasses of the Festuceae tribe are simple, and the inflorescence is an open or narrow panicle There are several to many spikelets 2 or more being perfect, the pediceled florets falling from the glumes at maturity and the lemmas longer than the glumes The tribe Festuceae is one of the largest of the grass family, containing more than 100 genera and over 1000 species It includes a large number of the most valuable range and hay plants of the temperate region The most important forage species are contained in 6 genera fescues, blue grasses, melicgrasses, bromes, saltgrasses, and mannagrasses Two introduced cultivated species, orchard grass (*Dactylis glomerata*) and meadow fescue (*Festuca elatior*), are valuable hay plants

Fescues (*Festuca*)

The fescues are annual or perennial grasses with simple culms, usually narrow, often inrolled leaves, open or narrow panicles, narrow and sharp pointed glumes, and lemmas that are mostly awned from the

tip. Some 34 of about 100 existing species occur in the United States. Among the most widely distributed and important are 4 bunchgrasses: Idaho fescue, Arizona fescue, sheep fescue, and western fescue. These species occupy dry foothills and open woodlands of intermediate to high elevation, with Idaho the center of their distribution. A few other species such as alpine fescue and greenleaf fescue are of localized importance. The perennial fescues are readily consumed, especially when succulent, by all kinds of livestock. Several annual fescues abundant in the foothills of California, are grazed to advantage only when green. Typical among them is the early-maturing foxtail fescue (*F. megalura*) (Fig. 37*E*), a common Pacific Coast species which is rated as "fair," being useful chiefly when green. Most of the perennial forms occupy areas of high successional development, though they seldom compose the dominants of the climax stage.

23. Idaho Fescue (*F. idahoensis*). This grass produces large bunches, has culms 1–3 feet tall, numerous, long, rough leaves, a narrow panicle that bears 2- to 7-flowered spikelets, and lemmas with awns ⅛–¼ inch long (Fig. 37*A*). Idaho fescue grows in open wooded and rocky slopes from Alberta to British Columbia, south to northern New Mexico, Arizona, and California. It sometimes comprises a large part of the cover between elevations of 5000 to 10,000 feet. The herbage is highly palatable up to maturity and is grazed with fair relish in the autumn after the leafage has cured. Abundant "aftermath" growth is produced on range grazed only up to midsummer. The general forage rank is "excellent."

24. Arizona Fescue (*F. arizonica*). This species closely resembles Idaho fescue, but the foliage is stiffer and more glaucous, also, the plant is smaller, and the lemmas are awnless or nearly so. It grows in open pine woods in Arizona, Nevada, New Mexico, and Colorado between elevations of 6000 to 10,000 feet. Arizona fescue is moderately palatable up to maturity, particularly to cattle and horses. In late summer the herbage decreases somewhat in palatability. In Arizona, heavy grazing of this plant in the ponderosa pine belt during the dry periods results in serious damage to timber reproduction (*6*). The over all forage value is "excellent."

25. Sheep Fescue (*F. ovina*). Sheep fescue is a densely tufted perennial 7–16 inches high, with the slender blades inwardly rolled and rather rough, the panicle is narrow, and the lemmas are about ⅛ inch long, terminating in a short awn (Fig. 37*B*). It grows in open woods and on stony slopes from North Dakota to Washington and Alaska and south to Arizona and New Mexico. It has been introduced into Michigan, Maine, Illinois, and South Carolina where some fair stands

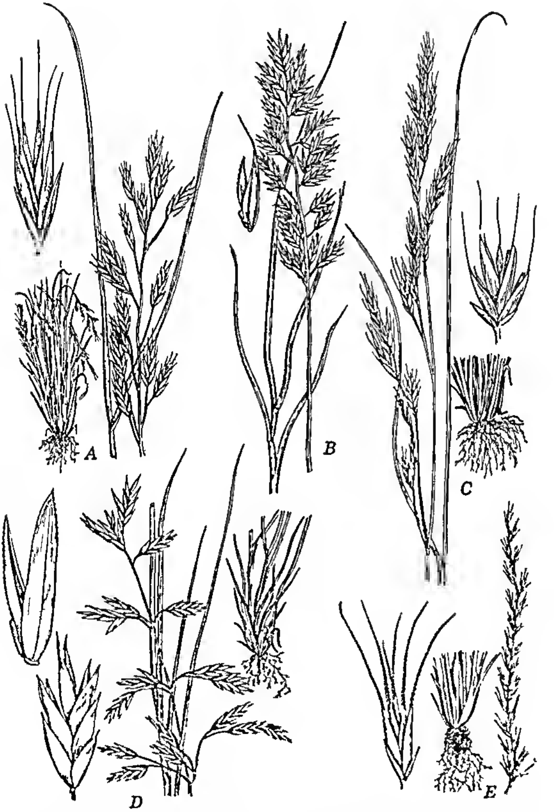


FIG. 37. *A*, Idaho fescue (*Festuca idahoensis*), *B*, sheep fescue (*F. ovina*), *C*, western fescue (*F. occidentalis*), *D*, greenleaf fescue (*F. viridula*), *E*, foxtail fescue (*F. megalura*)

occur It has also been used successfully in reseeding some western mountain ranges Sheep fescue furnishes superior forage for all kinds of stock, and the fine, bluish green leafage is often grazed beyond the endurance of the plant The general forage value is 'excellent

26 Alpine Fescue (*F ovina* var *brachyphylla*) This variety of sheep fescue has short culms and smooth, rather lax blades It occurs in the Arctic regions, south to the San Francisco and the San Bernardino Mountains, and in the Rocky Mountains to northern New Mexico, also in the higher mountains in Vermont, New Hampshire, and New York The forage value is similar to that of sheep fescue, but, being smaller and of more local importance, its general forage rank is good

27 Western Fescue (*F occidentalis*) The leaf blades of this species are mostly basal and the panicle is loose, 3–8 inches long, and often drooping (Fig 37*C*) It grows on dry, rocky, wooded slopes and banks from British Columbia to central California, east to Wyoming northern Michigan, and western Ontario, between elevations of 5000 and 10 000 feet The herbage is highly palatable at all seasons, its chief drawback being its sparse growth The general forage value is 'good

28 Greenleaf Fescue (*F viridula*) This species is best characterized by the dense tufts, the reddish nodes and base, the soft, abundant foliage, the nodding panicles which are 3–5 inches long, and the spikelets of variegated purple and yellowish green which fade at maturity (Fig 37*D*) Greenleaf fescue is a subalpine mountain bunchgrass which grows in meadows and on plateaus between elevations of about 6500 to 10 000 feet, from British Columbia to Alberta, south to central California and Idaho Throughout its rather narrow range, this robust plant produces a large amount of forage of unusually high quality Effective methods of revegetation of greenleaf fescue were reported by the author in 1914 (*23*) The general forage value is "good'

Bluegrasses (*Poa*)

These are slender, mostly perennials having soft foliage, leaf blades with a boat-shaped tip, loose or narrow panicles of small, awnless spikelets, and lemmas often with cobwebby hairs at the base The bluegrasses include more than 200 species, some 64 of which occur in the United States They supply a large amount of excellent forage throughout the grazing season, chiefly over areas of cold winters and warm summers (*26*) Because of their short stature the bluegrasses are seldom cut for hay The more widely distributed and important bunchgrass forms are muttongrass pine bluegrass, Nevada bluegrass,

and Sandberg bluegrass In the southern states, from Oklahoma and Texas to South Carolina and Florida, Texas bluegrass (*P arachnifera*) contributes considerable winter forage The primary sodformers are Kentucky bluegrass and Canada bluegrass, both being introduced but now growing wild, and Wheeler bluegrass, all three of which, like other sodformers, endure heavier grazing than the bunchgrasses Most bluegrasses are of high successional rank

29 Muttongrass (*P fendleriana*) This perennial bunchgrass is 1–2 feet tall, with pale-green, smooth foliage, numerous narrow leaves, mostly basal, and narrow, dense panicles 1–3 inches long with 4- to 8-flowered spikelets (Fig 38*A*) Muttongrass is found on mesas, in open, dry woods, and on rocky hills from Manitoba to British Columbia, south throughout western South Dakota and Idaho to western Texas and California, mostly between elevations of 7000 to 12,000 feet It is highly nutritious and remains palatable throughout the season to domestic stock, deer, and elk The general forage value is "excellent"

30 Pine Bluegrass (*P scabrella*) This perennial bunchgrass grows 1–3 feet tall and has numerous, mostly basal leaves 3–7 inches long and a panicle of 2–5 inches with spikelets ¼ inch long (Fig 38*B*) Pine bluegrass grows in meadows, open woods, and hills at low and medium altitudes, from western Montana and southern Washington to California It occupies fairly dry, often thin soils such as scablands and tends to mature rather early The copious, basal green leafage is highly palatable to all kinds of stock and is sought, especially by horses, after maturity (*9, 16*) The general forage value is "good"

31 Nevada Bluegrass (*P nevadensis*) Nevada bluegrass is a tufted, grayish green perennial, 1½–3 feet tall, with culms rough below the narrow, dense panicle and inrolled, mostly basal, leaves (Fig 38*C*) It occupies meadows and plateaus from Montana to eastern Washington and the Yukon territory, south to Colorado and California, from 3000 to 11,000 feet in elevation Although this species is seldom abundant in any one locality, it provides a fairly large amount of superior early spring and summer forage In the autumn the herbage becomes somewhat harsh, and, although grazed by cattle and horses, its nutritive value is rather low The general forage value is "good"

32 Sandberg Bluegrass (*P secunda*) This perennial bunchgrass has smooth culms 1–2½ feet tall, dense, blue-green basal leafage, and 3- to 5-flowered spikelets It is strictly a western species and occurs throughout the southern half of Saskatchewan, northwest to the Yukon, south throughout the western half of the Dakotas to southern Colorado, on to the coast of southern California This species is confined chiefly

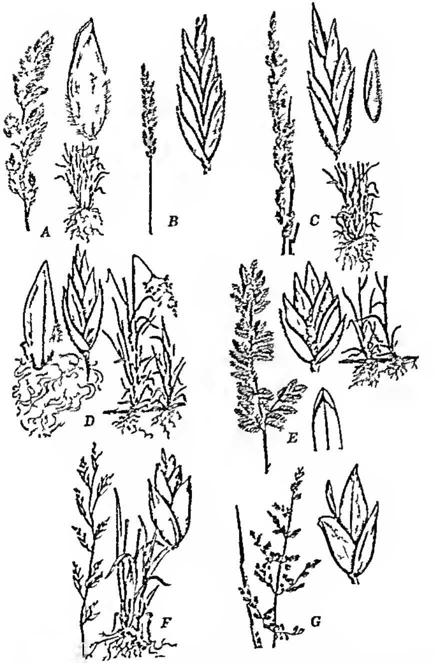


Fig. 38 *A*, Muttongrass (*Poa fendleriana*), *B*, pine bluegrass (*P scabrella*), *C*, Nevada bluegrass (*P nevadensis*), *D*, Kentucky bluegrass (*P pratensis*), *E*, Canada bluegrass (*P compressa*) *F*, bulbous melic (*Melica bulbosa*), and *G*, California melic (*M imperfecta*)

to middle and low elevations and is characteristic of scablands, rocky knolls, sagebrush flats, and exposed sites. It is of first quality as early forage and is also eagerly consumed after curing in the autumn. It endures grazing better than many other bluegrasses. The general forage value is "good."

33. Kentucky Bluegrass (*P. pratensis*). This introduction from England is one of the most important domesticated grasses in North America. It is a sodgrass, 1–3 feet tall, with soft, long foliage, an open panicle with spikelets that are clustered toward the ends of the branches, and lemmas copiously webbed at the base (Fig. 38*D*). At its best Kentucky bluegrass forms a dense sod, but it often grows in small patches. It occupies woodlands, meadows, and open ground up to timberline, being widely distributed from volunteer seeding throughout the United States and northward, except in arid regions and in the Southeast. Kentucky bluegrass is highly palatable and is cropped by game animals in the spring and by domestic stock at all seasons. It endures close grazing better than most species and does best when kept grazed down. It also ranks high for range reseeding and for lawns. The general forage rating is "excellent."

34. Canada Bluegrass (*P. compressa*). This European-introduced plant is a smooth, blue-green perennial with rootstocks. It closely resembles Kentucky bluegrass but is of lower stature, has a more open growth habit, bluer color, more flattened stems, a narrower panicle, and has a more scant web at the base of the lemma (Fig. 38*E*). The range is almost throughout North America, but it grows best in the eastern United States. Although it does well in soils too poor for Kentucky bluegrass, the yield is heaviest in clay loam soils. Canada bluegrass is essentially a pasture grass. It is closely grazed by all foraging animals if not allowed to become too rank in growth. Regeneration continues throughout the season where the herbage is kept grazed down. The forage rank is "good."

35. Wheeler Bluegrass (*P. nervosa*). This species grows 1–3 feet tall and may be distinguished from the other native bluegrasses by its running rootstocks, the rather rigid, slightly rolled leaves 3–8 inches long, and the open panicle about 5 inches long with its slender branches that are mostly in pairs, bearing spikelets of 3 to 4 florets. It is found in open woods, dry meadows, and on old burns of medium altitudes, from Alberta and British Columbia, south in the mountains to Colorado, New Mexico, and California. The abundant forage yield is palatable to all kinds of stock throughout the growing season. The general forage value is "good."

Melicgrasses (*Melica*)

The melicgrasses, also called oniongrasses, are perennials, forming dense or rather loose clumps, with simple culms often bulblike at the base, leaf sheath margins united except at the summit, and open or narrow panicles with 2- to several-flowered spikelets The glumes are thin, broad, shorter than the florets, 3 to 5 nerved, the lemmas are rather firm, strongly nerved below, thin and shining toward the apex, rounded on the back, awned in a few species, the upper lemma empty, aggregated into a club shaped mass, the grain is free, oblong or broadly spindle-shaped, and channeled Approximately 60 species of melicgrasses have been described, some 18 of which occur in the United States They are most common in the Rocky Mountains and the Pacific Coast regions The melicgrasses are fairly palatable, but, because of their characteristic scattered growth, are classed as "fillers," that is, secondary forage Bulbous melic and California melic are among the most important forage species

36 Bulbous Melic (*M bulbosa*) This robust perennial bunchgrass grows 2–4 feet tall, has stems with a somewhat bulbous base, rough sheaths, erect brown or green panicles 3–7 inches long, with spikelets ½ inch long bearing 5 to 8 perfect florets (Fig 38*F*) Oniongrass grows sparsely from western Montana to British Columbia, south to Colorado and California Its favorite habitat is in the mountains where it occupies well drained meadows and open woodland from sea level to 10,000 feet in elevation The herbage is grazed up to maturity by all kinds of stock and by deer and elk, but its sparse growth reduces its forage value which is rated as "fair"

37. California Melic (*M imperfecta*) This is a slender, erect, perennial bunchgrass, 1–3 feet tall, the culms not bulblike at the base The panicle is 3–12 inches long, with spikelets scarcely ¼ inch long, purple-tinged, and usually having 1 perfect floret (Fig 38*G*) Its range is limited chiefly to California and Lower California where it grows rather sparsely in dry, open woods and on rocky hillsides at low and medium altitudes California melic is one of the most palatable of the melics Although it does not withstand heavy grazing, it reproduces well by seed The general forage rating is "fair"

Bromegrasses (*Bromus*)

The "bromes" are coarse annual or perennial grasses with flat leaves, mostly drooping panicles, glumes that are shorter than the florets, the first 1- to 3-nerved, the second 3- to 9 nerved, lemmas that are usually rounded on the back, the tip being minutely 2-toothed and awnless or

with awns that arise from just below the tip, grains that are large, amber-colored, prominently grooved, and adherent to the palea. Of about 100 species of bromegrasses 36 are found in the United States. The most important on the western range, either because of their high forage rank or because of their objectionable features, are rescue grass, California brome, mountain brome, Pumpelly brome, soft chess, ripgut, foxtail chess, and downy chess. Smooth brome (*Bromus inermis*) is a valuable introduced hay and pasture grass that is used extensively in range reseeding. The bromes are medium to low in successional development.

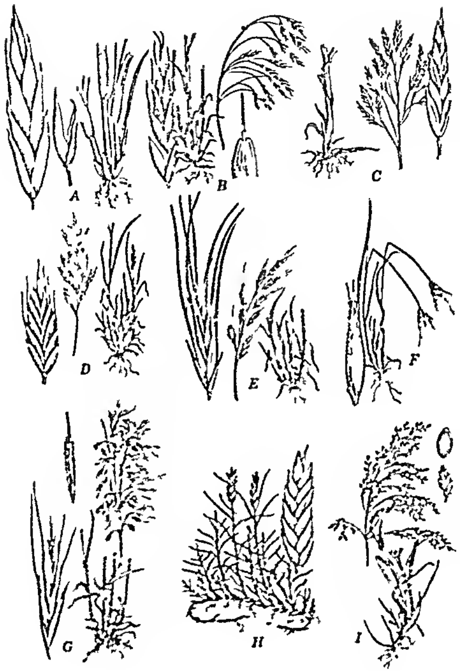
38. Rescue Grass (*B. catharticus*). An annual in the mild climate of the southern states and a biennial in its more northerly range, this species grows 1–3 feet tall. The leaf blades are narrow, rough or sparsely hairy, the sheaths are rough or hairy, the panicle is open with strongly flattened spikelets, the lemmas are compressed-keeled, and awnless or nearly so (Fig. 39*A*). Rescue grass, in addition to being a forage species of high repute in the south where it is often cultivated for winter pasture, occurs in varying abundance in moderately mild climates, including moist areas in the Southwest. The forage is eaten throughout the grazing season by all classes of stock with satisfactory results. The forage rating over its entire range is "fair."

39. California Brome (*B. carinatus*). This stout annual or biennial bunchgrass grows 1–4 feet tall, it has abundant, finely-hairy leafage and a panicle 4–8 inches long with erect branches that display spikelets 1–1½ inches long, containing 5 to 10 florets (Fig. 39*B*). California brome occupies open grounds of low to middle altitudes. It is common on the Pacific Coast and extends into British Columbia, Idaho and Montana to New Mexico and northern Mexico.

When young, this species is closely grazed by all kinds of stock. As the plant matures the herbage is less palatable, but the seed heads are eagerly sought by livestock. The yield of forage is large. Much aftermath growth is produced on areas grazed while the plant is still green. The large seed crop has prompted use of California brome for range reseeding in California. Sometimes a smut, *Ustilago bromivora*, attacks the seed heads, but the damage is seldom serious. Over-all forage rating of California brome is "excellent."

40. Mountain Brome (*B. marginatus*).[7] This form is a close relative of California brome and grows from 2–3½ feet tall, has soft, smooth

[7] Some agrostologists (6) regard the following forms as synonyms of *Bromus carinatus*: *B. marginatus*, *B. maritimus* (a strictly California coastal plant), and *B. polyanthus*, which occurs in the mountains of Colorado to Utah south to New Mexico and Arizona.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foliage and a branched panicle It occurs at middle elevations, being especially common on the Pacific coast and extending into British Columbia, east to South Dakota, Colorado, and western Texas, southward into northern Mexico It is an important pasture plant in the ponderosa pine and fir belts and is palatable to all stock, being similar in forage value to California brome The general forage rating is "good"

41. **Pumpelly Brome** (*B pumpellianus*). This stout, perennial species has culms 1½–4 feet tall, short basal leaves, creeping rootstocks, and erect panicles It resembles smooth brome (*B inermis*) but differs in having larger spikelets and awned florets (Fig 39C). It occupies meadows and hillsides between elevations of 5000 to 9000 feet from Colorado to the Black Hills of South Dakota, and to Idaho and Alaska This rather heavy yielder provides palatable forage for all kinds of stock and for game animals and withstands close grazing better than many other bromes The over-all forage rating is "good"

42. **Soft Chess** (*B mollis*). This densely tufted annual is 1–2½ feet tall, with velvety foliage and dense, oblong panicles that support downy spikelets (Fig 39*D*) A native of southern Europe, soft chess is widely distributed in the United States, being especially abundant on the Pacific Coast *The forage is good over its entire range, being taken* by all grazing animals In California, where it contributes heavily to the range forage, the author ranks soft chess as the most valuable of the annual grasses (*6*). After maturity, the plump seed heads are eaten with avidity by livestock, the animals making rapid gains and solid flesh on this feed The seeds are not scattered as soon as those of most of the other annual grasses Its general forage rating is "good"

43. **Ripgut** (*B rigidus*) This tufted annual, introduced from Europe, grows 1–2 feet tall and has stiff panicles and drooping spikelets that bear stiff awns 2–3 inches long (Fig 39*E*) It occurs from California to British Columbia and east to Idaho, Nevada, and Arizona, but rarely eastward. Ripgut is a common weed on open ground and in waste places in California, forming dense stands over large areas in the lowlands of its range The herbage is highly palatable when young, but the species is troublesome after reaching maturity, the long awns often causing injury to stock, especially sheep Because of its abundance and high palatability when young, the forage value is rated as "fair"

44 **Red Brome** (*B rubens*) This European, introduced, tufted annual grows 6–15 inches tall, has scant foliage, and reddish, heavily awned panicles resembling barley heads (Fig 39*F*) Red brome occurs in scattered stands on the Pacific slopes and throughout the Great Basin region It is grazed only in the spring, animals avoiding the herbage

after the prominent, troublesome awns have formed. The general forage rating is "poor."

45. **Downy Chess** (*B. tectorum*). This Mediterranean, introduced annual grows 15–24 inches tall. It has sparse foliage, narrow, finely-hairy leaf blades, panicles that droop at maturity, and spikelets with awns ½ to ¾ inch long (Fig. 39G). Downy chess is common throughout the United States except in the extreme South and along the California coast and is considered a weed in many localities. Although not highly palatable, downy chess occurs so extensively in the Rocky Mountains, Great Basin, and in parts of the Great Plains as to supply appreciable early spring forage of good quality, which is best utilized by cattle. The sharp-pointed, awned, mature florets cause some eye and mouth injury to both cattle and sheep (7). At maturity dense stands of downy chess sometimes cause so serious a fire menace that effort has been made to eradicate this grass in critical areas. The forage rating is "fair."

Saltgrasses (*Distichlis*)

This genus of low, rigid, leafy, dioecious perennials is characterized by strong, running rootstocks, panicles that are dense and small, spikelets that are flattened, smooth, and awnless, containing 6 to 15 florets, and lemmas that are somewhat rigid and indistinctly 7- to 11-nerved. There are 8 species of *Distichlis* in America and in Australia, 4 occur in the United States. They occupy alkaline or saline lands and are high in salt content.

46. **Desert Saltgrass** (*D. stricta*). This is the most widely distributed species found in all the western and most of the midwestern states (Fig. 39H). Seashore saltgrass (*D. spicata*) occurs abundantly along the coastal strip of the eastern, southern, and western states. These species are so nearly identical in forage value that they can be discussed together. They are rather low in nutritive value, but they do provide much pasturage that endures heavy use. The forage is better suited for cattle and horses than for sheep. Late in the season the herbage becomes tough and low in palatability, but if it is supplemented with a ration high in protein, cattle can be maintained in fair condition on saltgrass pasture until late in the fall. The general forage rating of the saltgrasses is "fair."

Mannagrasses (*Glyceria*)

These tall, semiaquatic, or marsh perennial grasses have flat leaves, narrow or spreading panicles, spikelets of few to many awnless florets, glumes of unequal length, thin and less than half as long as the florets

and greenish lemmas with 5 to 9 strong, parallel nerves. There are about 40 species of *Glyceria* in the temperate regions of both hemispheres with 20 species occurring in the United States, approximately one-third of which are found in the West. All of the mannagrasses are fairly palatable, but most species are narrowly distributed. Fowl mannagrass is probably the most important species.

47. Fowl Mannagrass (*G. striata*). This robust bunchgrass with culms 1–3 feet tall is the most widely distributed of the mannagrasses in the United States. It occurs from Newfoundland to British Columbia, south to California, Mexico, and Florida, from near sea level to about 10,000 feet in elevation (Fig. 39*I*). Favorite habitats are stream banks, wet meadows, marshes, swamps, and aspen and coniferous areas. The succulent herbage is eaten by all kinds of grazing animals and is rated good to excellent for cattle and horses and fair for sheep. Its value for forage is chiefly in the late summer when the soil is dry. A few cases of hydrocyanic acid poisoning have been ascribed to this species, but concrete evidence on this point is lacking. The general forage rating of this species is "good."

In the next chapter are discussed other important native range grasses and some grasslike plants of special importance as forage.

Literature cited in Chapter 8 is presented at the end of Chapter 9.

Chapter 9

OTHER NATIVE RANGE GRASSES, AND GRASSLIKE FORAGE PLANTS

Grama Tribe (Chlorideae)

The tribe Chlorideae is characterized by the one-sided spikes, racemosely or digitately arranged, and by the spikelets that have 1 to several florets arranged along one side of the rachis. Although including only 50 genera and 300 species, this tribe embraces many species that contribute much valuable forage to the western range. The most important genera are buffalo grass, the gramas, the valuable domesticated hay and pasture plant Bermuda grass (*Cynodon dactylon*), and the finger grasses (*1, 8, 23*).

Buffalo Grass (*Buchloe*)

48[1] Buffalo Grass (*B. dactyloides*). The staminate plants are larger than the pistillate forms of this low-growing dioecious, perennial, stoloniferous grass. The foliage is grayish green, and the leaves narrow, flat, and somewhat curly. The staminate spikelets are in a small, one-sided spike on a slender culm 4–8 inches tall, the pistillate spikelets are crowded 4 or 5 together in heads at the base of the lower sheaths, partly concealed by the leaves, and the florets are hidden by the outer glumes which form the hard covering of the heads (Fig. 40*A*). This drought enduring plains grass occurs in an area from western Minnesota and central Montana, south to Northwestern Iowa, Texas, western Louisiana, Arizona, and northern Mexico. It is usually associated with blue grama. Reproduction is largely accomplished by vegetative means from the stolons (*6, 29*). The herbage, although too short to cut for hay, furnishes superior pasturage throughout the year (*26*). The best development is attained in the Great Plains, where it often forms a climax cover. The general forage rating is "excellent."

Gramas (*Bouteloua*)

These annual or perennial bunchgrasses or sodgrasses have flat or rolled leaf blades, spikes crowded with short, stout, 1-flowered spike

[1] Numbering of plants discussed is continued from Chapter 8.

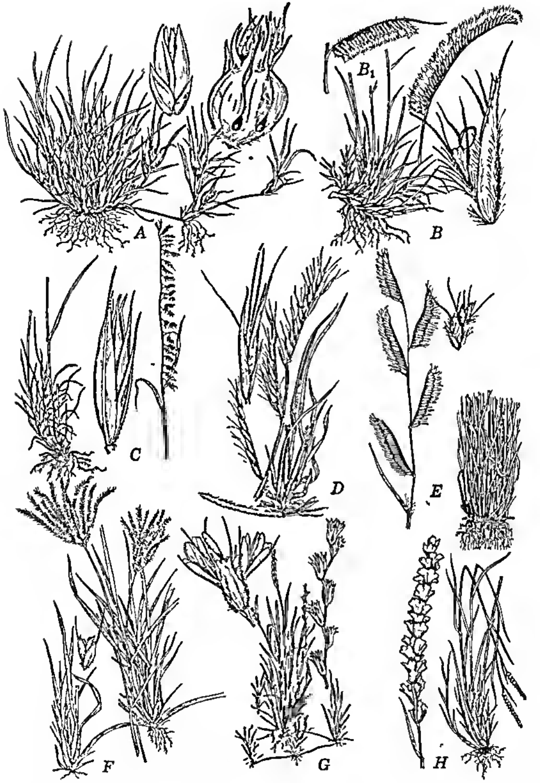

Fig. 40. *A*, Buffalo grass (*Buchloē dactyloides*); *B*, blue grama (*Bouteloua gracilis*); B_1, hairy grama (*B. hirsuta*); *C*, side-oat grama (*B. curtipendula*); *D*, black grama (*B. eriopoda*); *E*, Rothrock grama (*B. rothrockii*); *F*, Rhodes grass (*Chloris gayana*); *G*, curly mesquite (*Hilaria belangeri*), and *H*, tobosa grass (*H. mutica*).

lets with 1 or more modified florets above the fertile one, and grains that are oblong and free There are about 38 species of gramas, 17 of them in the United States They are most abundant in the Great Plains and southwestern United States, with Arizona the approximate center of distribution The gramas occupy dry soils from low altitudes to elevated plateaus The annual species are grazed only when green, but the perennials are among the most important forage plants in their natural habitats Blue grama, hairy grama, side-oat grama, and black grama are the leading species Of lesser importance are Rothrock grama, sprucetop grama, and slender grama The gramas frequently constitute the climax stand

49 Blue Grama (*B gracilis*) This loosely tufted, erect perennial grows 6–18 inches high, its narrow, short, and curly basal leaves are abundant, it has 1 to 2, rarely 3, dense, one-sided spikes about 1 inch long, and hairy glumes and lemmas, the lemmas with 3 short awns (Fig 40*B*) It ranges from Wisconsin to Manitoba and Alberta, south to Missouri, Texas, and southern California, and into Mexico, up to about 5500 feet in elevation Blue grama is very drought-enduring and ranks first among the gramas as forage The herbage is closely cropped by all stock when green or cured, making excellent yearlong pasturage as well as choice hay It endures heavy grazing or close cutting better than many grasses Under favorable moisture conditions it tends to form a loose sod The seed habits are fairly strong The general forage rating is "excellent"

50 Hairy Grama (*B hirsuta*) This perennial bunchgrass grows 4–30 inches tall and has leaf blades 2–8 inches long It closely resembles blue grama but is smaller, with shorter, broader, and more hairy spikes, and the rachis is prolonged into a stiff point beyond the last spikelet (Fig 40*B*1) Hairy grama occurs from Wisconsin and South Dakota to Texas, Colorado, Arizona, and California south through Mexico up to 7500 feet in elevation The forage is of high value for all stock, but, being less widely distributed than blue grama, it is not as important on the range The general rating is 'good'

51 Side-Oat Grama (*B curtipendula*) This loosely bunched perennial has culms 1–4 feet tall, strong, scaly, creeping rootstocks 4–12 inches long that produce many vigorous shoots and abundant leafage, and one-sided panicles 6–12 inches long bearing 25 to 50 nodding spikes on an elongated axis It grows typically as a bunchgrass, despite the presence of rootstocks (Fig 40C) It occupies plains and prairies from Maine and Ontario to Montana, south to Maryland, Alabama, Texas, Arizona, and southern California In the plains of Montana it produces a scattered stand, but in the Southwest it is often dominant on

dry slopes, ridges, and rocky hillsides between elevations of 3000 to 8000 feet. The abundant leafage is everywhere sought by stock, both when green and in winter after curing. The heavier stands are sometimes cut for hay. The over-all forage value is "good."

52. Black Grama (*B. eriopoda*). This stoloniferous species has jointed branches, densely woolly culms, numerous flaglike spikes, and conspicuous tufts of whitish, woolly hair at the bases of the loosely arranged spikelets. The lower parts of the stems are often perennial (Fig. 40*D*). Black grama occupies hills, mesas, and dry ground from Texas to southern Utah and northern Mexico and is most abundant between elevations of 3500 to 5500 feet. It grows best in open grasslands and on dry, gravelly or sandy soils. Originally it formed a nearly pure cover over extensive areas, and it still predominates under favorable conditions. The leafage is highly palatable and nutritious both in summer and winter. Although it withstands grazing fairly well, it spreads little on fully used ranges. The general forage rating is "excellent."

53. Rothrock Grama (*B. rothrockii*). This short-lived perennial has a meager root system and leafy culms, especially toward the base (Fig. 40*E*). It resembles blue grama, but it grows in small bunches and has more numerous and finer spikes. Rothrock grama occurs from southern Utah throughout Arizona and southern California into Mexico, being especially abundant on mesas and gentle, dry slopes of southern Arizona between elevations of 2000 to 5500 feet. The forage varies from fair to good in palatability during the summer growing season but does not cure as well on the range as many other common gramas. The general pasture value is "good."

54. Sprucetop Grama (*B. chondrosioides*). Sprucetop grama is an erect, perennial bunchgrass 1–3 feet tall, with numerous, slender, flat leaves, rather naked culms that commonly bear 3 to 7 woolly, bristly spikes, and spikelets that are borne in 2 comblike rows. In the United States this species is restricted to foothills and deserts from western Texas to southern Arizona, and Mexico. Though cropped most closely in the summer, it is moderately palatable yearlong, partly because of the numerous short leaf blades. The general rating is "fair."

55. Slender Grama (*B. filiformis*). This perennial grass is similar in appearance and growth habit to sprucetop grama but has larger, narrower spikes and nearly glabrous spikelets. It ranges from Texas to Arizona and Mexico. The herbage is palatable to all stock and cures well on the ground. The general rating is "fair."

56. Annual Gramas. Several annual species of gramas are common in the Southwest. Sixweeks grama (*B. barbata*) and Parry grama

(*B. parryi*) are common forms and needle grama (*B. aristoides*) is fairly common. These species furnish forage of value in the early spring. As a group their forage value rates "fair."

Finger Grasses (*Chloris*)

These are tufted perennial or annual grasses with flat or folded, rough leaf blades, 2 to several showy spikes digitate at the summit of the culms, and sessile spikelets, with 1 perfect floret and 1 or 2 sterile lemmas above it, arranged in 2 rows along one side of a continuous rachis, the rachilla disjointing above the glumes. Although no species of the genus is highly important, collectively they contribute considerably to the forage crop. The general forage value of finger grasses is "fair."

57. **Rhodes Grass (*C. gayana*), and Other *Chloris* spp.** Rhodes grass, introduced from Africa, is seeded for forage in the South, notably in Florida and Texas, where it is regarded favorably (Fig. 40*F*). Feather fingergrass (*C. virgata*), an annual, and windmill grass (*C. verticillata*), a perennial, are weeds in many localities, but they supply forage of some value early in the season.

Mesquite Tribe (*Zoysieae*)

The spikelets of these grasses are subsessile, in short spikes of 2 to 5, each spike falling entire from the continuous axis. They are mostly 1-flowered, the flowers perfect, but in *Hilaria* the 1-flowered perfect spikelet and the 2 flowered staminate spikelets are crowded together in the same spike. The glumes, sometimes awned, are usually firmer than the lemma and palea. The mesquite grass tribe embraces only 4 genera in the United States. One genus collectively called mesquite grasses, or hilarias, is important (*6, 21*).

Mesquites (*Hilaria*)

These are perennials, mostly turf forming, with flat or rolled leaves and terminal, solitary inflorescences of short, sessile spikes appressed to the continuous axis and falling entire. This genus includes only 5 species, 4 of which occur in southwestern United States. The most important are curly mesquite, galleta, and tobosa.

58. **Curly Mesquite (*H. belangeri*)** This leafy, wiry perennial has creeping stolons that produce a close, firm sod in favorable soil. The few leafy culms grow upright, 5–8 inches high, and are hairy at the nodes, the spike is purplish, loosely flowered, 1–2 inches long (Fig. 40*G*). Curly mesquite ranges only from central Texas to Arizona, and south to Central America. It is most common on the plains of Texas, southwestern New Mexico, and southern Arizona

The elevational range is from 1500 to 5500 feet. Curly mesquite is highly esteemed as forage and supplies excellent early feed. The herbage cures well on the ground and is palatable to all livestock at all seasons. It is unusually drought-resistant and withstands close grazing. The general forage value is "excellent."

59. Galleta Grass (*H. jamesii*). This erect perennial has numerous, rather wiry, dull green leaves, an inflorescence of chaffy appearance, finely hairy, often purplish, fading to almost white at maturity. It occupies mesas, plains, and deserts from Wyoming and Utah to Texas and Inyo County, California; it is most abundant in Arizona and New Mexico. Galleta grass has strong rootstocks, grows in bunches on dry sites, but forms a sod in moist soils. The abundant forage is of highest palatability and nutrition during the growing season. The general forage value is "excellent."

60. Tobosa Grass (*H. mutica*). This species resembles galleta but has coarser stems and somewhat tougher leafage; the culms are smooth or finely hairy at the joints with many sterile branches below (Fig. 40*H*). Tobosa grass ranges from western Texas to Arizona and New Mexico, growing typically on dry, open flats, depressions, and foothills. The herbage is palatable to all stock, especially when green and succulent. Although reproduction by seed is satisfactory, the strong rootstocks provide the surest means of regeneration. The general forage value is "good."

Timothy Tribe (Agrostideae)

This large tribe of some 58 genera is characterized by 1-flowered, perfect spikelets, borne in panicles. It includes 2 valuable European-introduced hay and pasture plants: meadow redtop (*Agrostis alba*) and timothy (*Phleum pratense*); in addition, several native species have fair to high pasture value. Some, however, decline in palatability early in the season, others grow too sparsely to supply much forage, still others occupy wet, acid soils which are not suitable for foraging until fairly late in the season. The most important genera are: redtops or bentgrasses, reedgrasses, muhlygrasses, timothies, needlegrasses, dropseeds, and ricegrasses. Those of lesser importance are: the three-awns, wolftails, hairy dropseeds, and sandgrasses (*6, 23*).

Redtops (*Agrostis*)

The redtops or bentgrasses are annuals or perennials with small spikelets and nearly equal glumes longer than the florets. Of about 100 existing species, 32 are found in the United States. Redtops are especially abundant on acid soils in the Pacific Northwest. Several intro-

duced forms of bentgrasses are used on lawns and golf courses Meadow redtop (*Agrostis alba*) is extensively used in range reseeding (Chapter 11) Some of the native species rank high in succession This genus rates fairly high as forage among the perennial grasses in America Spike redtop a native bunchgrass, is typical in forage value of the better native forage species of *Agrostis*

61 Spike Redtop (*A exarata*) This pale-green, leafy perennial grows 1–4 feet tall, with erect, densely flowered panicles 2–10 inches long, mostly contracted or occasionally open, tapering to a slender summit The florets usually have awnless lemmas (Fig 41*A*) Spike redtop is widely distributed and occurs from western Nebraska to Alberta and Alaska south to New Mexico, California, and Mexico The herbage is moderately palatable to domestic stock, deer, and elk It reproduces entirely by seed Its general forage value is "good"

REEDGRASSES (*Calamagrostis*)

These tall perennials are bunchgrasses or sodformers The panicle is large, open, or restricted, with small spikelets having a hairy callus at the base of the lemma and a rachilla joint produced beyond the base of the palea, the rachilla having hairs at least half as long as the lemma The reedgrasses comprise over 100 species, 23 of which occur in the United States Bluejoint and pinegrass, although not of high forage rank, are typical of the genus (*6, 23*) Both species are fairly high in the succession

62 Bluejoint (*C canadensis*) This tufted perennial has numerous creeping rhizomes, wide, lax leaf blades, an open panicle, and spikelets with long, copious hairs and straight, slender awns (Fig 41*B*) It occurs from sea level to 12,000 feet in elevation, from Labrador to Alaska south to Maryland, North Carolina, Missouri, Kansas, Colorado, Arizona, and California Bluejoint produces much forage of moderate palatability, especially for cattle The marshy or wet soil that it occupies tends to preclude early season grazing The general forage value is "fair"

63 Pinegrass (*C rubescens*) This tufted perennial has strong creeping rootstocks, culms 1–3 feet high, abundant, basal, inrolled leafage, a ring of stiff, short hairs at the junction of the leaf sheaths and blades, panicles 3–6 inches long, purple or pale-green, narrow, and densely flowered, nearly smooth glumes about ⅛ inch long, and thin, sharp pointed, whitish lemmas (Fig 41*C*) Pinegrass grows from Manitoba to British Columbia, south to northern Colorado and Central California, ranging up to about 10,000 feet in elevation It grows best at medium elevations in open, dry ground of the ponderosa and

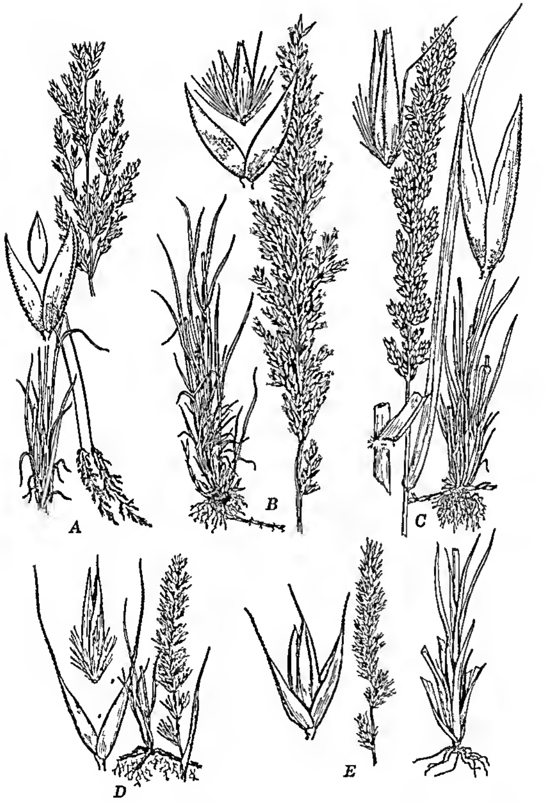

FIG. 41. *A*, Spike redtop (*Agrostis exarata*), *B*, bluejoint (*Calamagrostis canadensis*); *C*, pinegrass (*C. rubescens*); *D*, marsh muhly (*Muhlenbergia racemosa*), *E*, spike muhly (*M. wrightii*).

lodgepole pine belts The leafage is grazed moderately by cattle, sheep and horses up to early summer but becomes tough and unpalatable thereafter Pinegrass areas must be grazed lightly to save the highly palatable forage species that typically occur in the stand Although these more palatable species form but a small part of the plant cover, they usually make up an important part of the usable forage The general rating is "fair

MUHLYGRASSES (*Muhlenbergia*)

These perennial or annual grasses have small, pointed spikelets, and lemmas usually longer than the glumes 3 nerved, awned from the tip or just below it. The muhlys include some 120 species, 40 being found in the United States principally in the Southwest They seldom grow densely, hence they provide only a moderate volume of forage The most important species are marsh muhly and spike muhly, both of which are sodformers, and bush muhly, a bunchgrass (*15, 29*)

64 Marsh Muhly (*M racemosa*) This erect or suberect perennial has creeping rhizomes, narrow leaf blades, and condensed panicles with awn tipped glumes, the awn exceeding the awnless lemma (Fig 41*D*) Marsh muhly occupies moist sites and low grounds from Newfoundland to British Columbia, south to Maryland, Kentucky, Oklahoma and Arizona The elevational range is from near sea level to 8500 feet. The herbage is palatable to all stock throughout the growing season If cut before seed maturity, it makes satisfactory hay The general forage rating is "good"

65 Spike Muhly (*M wrightii*) This tufted perennial has flattened stiff, usually erect culms narrow leaves and dense, spikelike panicles (Fig 41*E*) The range is from Colorado and Utah throughout the Southwest, mostly on wooded lands between altitudes of 5500 to 9000 feet It is adapted to many conditions but is abundant only in localized areas Spike muhly is among the most palatable species of the genus, being sought by all stock, and it endures grazing rather well The general forage rating is "good"

66 Bush Muhly (*M porteri*) This branched, stiff stemmed slender, perennial bunchgrass grows up to 2 feet tall, has open panicles 2–3 inches long and spikelets about ¼ inch long, the lemmas being short awned Bush muhly, a strictly western species, extends from western Texas to Colorado, Nevada, and southern California, ranging up to 7000 feet in elevation It is most abundant on dry mesas and ridges of the Southwest Although seldom growing densely, bush muhly is nevertheless a valuable forage plant The herbage when green is grazed avidly by all stock, when it is dry, with moderate gusto The

perennial culms, which are coarse but not tough, are devoured in the winter by cattle and horses almost as closely as are the leaves. It does not stand close grazing or heavy trampling. The general forage rating is "good."

TIMOTHIES (*Phleum*)

These are perennial grasses with erect culms, flat leaf blades, dense spikelike panicles, cylindrical or oval-oblong, flat, 2-horned spikelets, and awned glumes. Of the 10 existing species of *Phleum,* alpine timothy is the only native species in America.

67. Alpine Timothy (*P. alpinum*). This tufted perennial grows ½–2 feet tall, has somewhat bent, semicreeping culms, flat, smooth, wide leaves, and dense, oval-oblong panicles ½–2 inches long, usually purple. It is distinguished from cultivated timothy (*P. pratense*) by its lower stature, shorter leaf blades, and shorter, oval-oblong panicle (Fig. 42*A* and *B*). Alpine timothy is common in mountain meadows and wet sites from Greenland to Alaska, south to Maine and New Hampshire, northern Michigan, and the mountains of the western states. The herbage is relished by all domestic stock, particularly cattle and horses, and by elk and deer. It withstands grazing well. The general forage rating is "good."

NEEOLEGRASSES (*Stipa*)

These are perennial bunchgrasses with numerous, mostly basal, narrow or rolled leaves, open or narrow panicles, narrow, long-awned spikelets, and hardened lemmas ending in a long, bent, twisted, and sometimes feathery awn. There are about 100 species of needlegrasses throughout the temperate regions of both hemispheres. Some 34 species occur in the United States, most abundantly in the Southwest. Most needlegrasses are grazed by all herbivores. The awns and the sharp-pointed seeds occasionally cause annoyance to stock. The seeds are self-planted by virtue of the twisting of the awn. The successional rank is high. The most important forage species are: green needlegrass, needle-and-thread, sleepygrass (all of which are discussed below to represent the forage value of the genus), Columbia needlegrass, Letterman needlegrass, western needlegrass, and foothill needlegrass (*6*, *23*).

68. Green Needlegrass (*S. viridula*). This coarse grass grows 1½–3 feet tall, has abundant basal, inrolled leafage, green, loosely spikelike panicles 4–8 inches long, and rather short, twice-bent awns (Fig. 42*C*). It occurs on plains and dry slopes between 2000 and 9000 feet in elevation, from New York and Wisconsin to Alberta, south to Kansas and New Mexico. The herbage is palatable and often succulent throughout

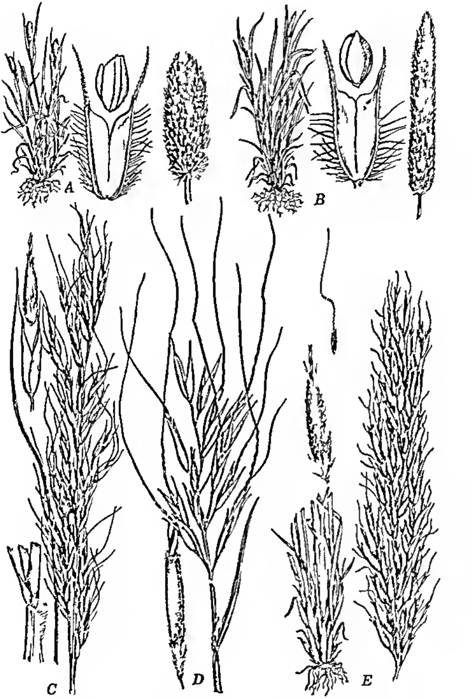

FIG. 42 *A*, Alpine timothy (*Phleum alpinum*), *B*, cultivated timothy (*P pratense*) *C*, green needlegrass (*Stipa viridula*) *D* needle-and thread (*S comata*), and *E*, sleepy grass (*S robusta*)

the summer, and is especially sought by cattle and horses The general forage rating is "good."

69. Needle-and-Thread (*S. comata*). Needle-and-thread is recognized by the loosely curled awns 4–6 inches long and the loose, pale panicles 6–10 inches long (Fig 42*D*). It occupies dry, sandy plains, mesas, and foothills up to 8500 feet in elevation, from Indiana to the Yukon Territory, south to Texas and California The forage value varies in different regions, but the leafage is usually palatable in the spring and again in the autumn after the seeds have been shed The abundant herbage cures well and is often grazed closely in the winter. In some localities the stand has been seriously thinned by overgrazing The general forage rating is "good"

70. Sleepygrass (*S. robusta*) This coarse bunchgrass has light-green foliage, grows 3–6 feet tall, has leaf sheaths fringed at the throat with numerous white hairs, often sparsely hairy on the margins, densely flowered panicles up to 1½ feet long, and glumes about ⅓ inch long with hairy lemmas ¼ inch long and twice-bent awns 1–1½ inches long (Fig. 42*E*). Sleepygrass grows in scattered stands in open canyons, hillsides, and parks from Colorado and western Texas to southern California and into Mexico, from 5000- to 9000-foot elevations The herbage is low in palatability but is sometimes grazed closely in the absence of better forage It is reported to be mildly poisonous to livestock, although authorities disagree regarding its effect (*17*, *25*). It is said to produce a narcotic reaction in horses and sleepiness in cattle and sheep, but the poisonous substance has not been isolated. The general forage rating is "poor."

Dropseeds (*Sporobolus*)

The dropseeds are perennial or, rarely, annual grasses, with narrow, spikelike, or loose, spreading panicles and small spikelets, the lemma 1-nerved, awnless, thin, shining, and longer than the glumes About 100 species grow in the tropical and temperate regions of both hemispheres, 36 of them in the United States Many dropseeds are leafy, and they are palatable to all stock Alkali sacaton, sacaton, and sand dropseed are among the most valuable species Some species thrive on alkali lands of the Southwest, where they provide hay and pasture primarily for horses and cattle (*29*).

71. Alkali Sacaton (*S airoides*) This robust, rigid perennial bunchgrass, called alkali dropseed in some localities, grows 1–3 feet tall, has narrow leaves, smooth beneath and rough above, a pale, open, pyramidal panicle 5–15 inches long, spikelets $\frac{1}{16}$–$\frac{1}{12}$ inch long, glumes that are sharp-pointed and nerveless, the first half as long as the second, and

lemmas blunt at the tip and about the same length as the second glume (Fig 43*A*) It occupies alkali flats and open plains from Washington, northern South Dakota and Missouri south to central Texas and southern California In the Southwest, the denser stands produce abundant herbage which is grazed moderately during the growing season by all stock Upon maturity alkali sacaton is of low palatability and is cropped but lightly in winter The over all forage value is "fair"

72 Sacaton (*S wrightii*) This stout, perennial bunchgrass grows 2–8 feet tall, has leaves 1–2 feet long, rolled or sometimes nearly flat and a narrow panicle, 1–2 feet long, the spikelets being about $1/10$ inch long (Fig 43*B*) Sacaton occupies alluvial fans and arroyos up to 7000 feet in elevation from southern California and northern Texas southward throughout the northern half of Mexico Formerly it produced dense stands on river bottoms in the Southwest The herbage is grazed by all stock early in the season but only moderately after maturity The general forage rating is "fair"

73 Sand Dropseed (*S cryptandrus*) This perennial bunchgrass grows in small clumps and is recognized by the conspicuous tufts of long white hairs at the summit of the sheaths It inhabits sandy or gravelly soils up to 8000 feet in elevation from Maine and Ontario to Alberta and Washington, south to North Carolina, Indiana, Louisiana, Arizona, and northern Mexico The best stands occur in the Southwest, where it sometimes spreads rapidly It is a prolific seeder and reproduces well under rational management The green herbage is grazed with gusto by all stock and is fair to good winter forage (*6, 29*) The general forage rating is "fair"

Ricegrasses (*Oryzopsis*)

These are perennial bunchgrasses with flat or rolled leaves, narrow or open panicles, and short, thick lemmas with short awns that fall at maturity There are about 25 species of ricegrasses, 15 occurring in the United States Many are palatable, but few are abundant Smilo or San Diego grass (*O miliaceae*), introduced from the Mediterranean region, is used for range reseeding in California Indian ricegrass is the most important native forage species

74 Indian Ricegrass (*O hymenoides*) This dense bunchgrass grows 1–2 feet tall, has spikelets in loose, spreading panicles 6–12 inches long, branches in pairs, leaves flat or inrolled, 6–15 inches long, glumes persistent, broad, 3- or 5-nerved, lemmas about one half as long as the glumes, florets white silky, and awn straight, up to ¼ inch long (Fig 43C) It grows in scattered stands on dry, sandy soils with sagebrush, mesquite grasses, and gramas from Manitoba to British

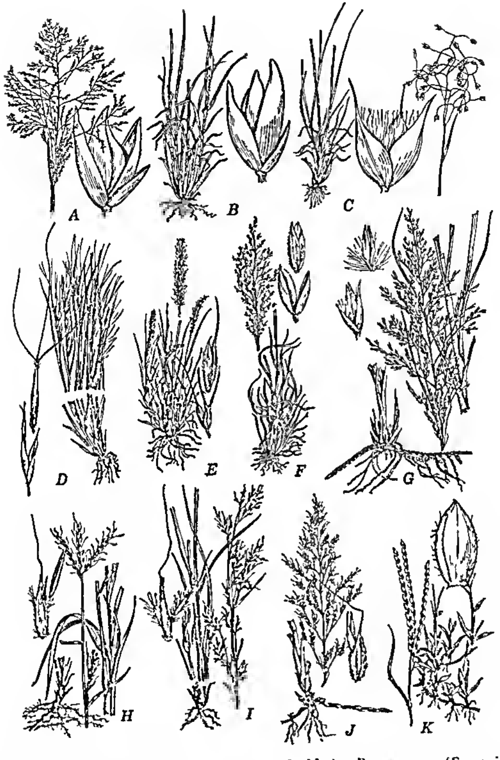

FIG. 43. *A*, Alkali sacaton (*Sporobolus airoides*); *B*, sacaton (*S. wrightii*); C, Indian ricegrass (*Oryzopsis hymenoides*); *D*, red three-awn (*Aristida longiseta*); *E*, wolftail (*Lycurus phleoides*); *F*, pine dropseed (*Blepharoneuron tricholepis*); G, prairie sandgrass (*Calamovilfa longifolia*); *H*, big bluestem (*Andropogon gerardii*); *I*, little bluestem (*A. scoparius*); *J*, Johnson grass (*Sorghum halepense*); and *K*, true carpet grass (*Axonopus compressus*).

Columbia, south to Texas and California. The herbage is consumed by all stock early in the season and also in autumn and winter. The large, numerous seeds are much sought by stock. Formerly this was one of the most common grasses of desert ranges, but overgrazing has destroyed much of the stand. It responds favorably to deferred grazing. The general forage value is "good."

Three-Awn (*Aristida*)

These grasses, also called "dogtown grass," are recognized by the 3-cleft awn and the sharp pointed, stiffly hairy base of the lemmas. There are about 200 annual and perennial species of three awns, some 36 of which occur in the United States, mostly in the South and Southwest. They vary in forage value, collectively ranking low, but they do supply early spring feed of fair quality, especially in the Southwest. Red three awn is fairly typical of the perennial species.

75. Red Three-awn (*A. longiseta*). This densely cushioned bunchgrass grows 1½–2 feet tall, has sharp-pointed, inrolled leaves, erect narrow panicles, purplish spikelets, lemmas about ½ inch long, and awn divisions up to 4 inches long (Fig. 43*D*). It occupies dry, sandy soils of plains, foothills, and mesas over much of the region west of the Mississippi. The forage value varies from nearly worthless to satisfactory, depending largely on the associated vegetation and on the season when pastured. The general forage rating is "fair."

Wolftails (*Lycurus*)

The wolftails are slender perennials with grayish, bristly, spikelike panicles, and spikelets that are borne in pairs, the lower pair sterile, the two falling together. Only 1 species occurs in the United States.

76. Wolftail (*L. phleoides*). This species is sometimes confused with timothy, but it has narrower leaves and more slender heads with longer, slender awns (Fig. 43*E*). It grows typically in scattered stands between elevations of 4000 to 8000 feet from western Texas, New Mexico, and Arizona south into Mexico. Wolftail produces good forage, 50 to 75 percent of which may be grazed yearly on properly managed areas. The foliage cures well on the ground. With the advent of rainy weather the semiperennial stems again become succulent and palatable. The general forage rating is "good."

Beardless Pinegrass (*Blepharoneuron*)

This perennial bunchgrass has narrow, open panicles, with subequal rather broad glumes and 3-nerved lemmas, the nerves densely silky hairy.

77. Pine Dropseed (*B tricholepis*) This is the only species of the genus (Fig 43F) It occurs in mountain glades or parks, or in open timber on moderately dry, rocky soils from Colorado and Utah to Arizona, western Texas, south into Mexico The young growth is palatable to all livestock, being about equal to that of mountain muhly The stems and seedheads are usually ignored or are lightly grazed late in the season The general forage rating is "good"

Sandgrasses (*Calamovilfa*)

These are rigid, usually tall perennials with creeping rhizomes, narrow or open panicles of short-pediceled spikelets, unequal, 1-nerved glumes, and 1-nerved, awnless lemmas There are only 4 species of *Calamovilfa* in the United States, 2 occurring in the West Prairie sandgrass is the most important forage species

78 Prairie Sandgrass (*C longifolia*) This drought-enduring species grows 2–6 feet tall, has strong, scaly rhizomes, tapering, long, slender leaves, and glumes shorter than the floret (Fig 43G) It occupies dry, sandy soils from Michigan to Alberta, south to Indiana, Colorado, and Idaho The forage is lightly grazed during the growing season but is important as winter pasture and for hay The strong rhizomes are effective in binding loose, sandy soil The general forage rating is "fair"

Sorghum Tribe (Andropogoneae)

The tribe Andropogoneae is characterized by the hardened glumes and by the paired spikelets, 1 perfect and sessile, the other pediceled and usually sterile, borne on a usually jointed rachis forming slender racemes The tribe includes about 65 genera, of which the bluestems are the most important as forage The sorghums and Indian grasses also have some pasturage value (*8, 23*)

Bluestem Grasses (*Andropogon*)

These are slender, somewhat coarse, solid-stemmed perennials with long, narrow leaves and terminal or axillary racemes There are approximately 200 species of bluestems, some 32 occurring in the United States They are most abundant in the southeastern states and in the Midwest Most bluestems are grazed up to late summer, but after the seeds ripen the foliage becomes rather unpalatable and low in nutrition Big bluestem and little bluestem are the most important species

79 Big Bluestem (*A gerardi*) Until recently known as *A furcatus*, this robust, bluish green climax perennial has short rhizomes, grows 3–6 feet tall, has flat leaf blades with rough margins, has 2 to 6

purplish racemes 2–4 inches long digitate on a long exserted peduncle, has sessile spikelets about ⅜ inch long, the awns tightly twisted below and about ½ inch long (Fig 43*H*) Big bluestem occupies dry habitats prairies and open woods of medium elevations from Quebec and Maine to Saskatchewan and Montana, south to Florida, Texas, Wyoming, Utah and Arizona Forage production is exceptionally large When succulent, the herbage is highly palatable to stock, but the mature leafage is not grazed by choice (*8, 16*) The denser stands are often cut for hay The general forage rating is "excellent"

80 Little Bluestem (*A scoparius*) This purplish or bluish green perennial bunchgrass has erect culms 1–3 feet tall, the upper half branching freely, racemes 1–2½ inches long, slender axis flexuous hairy, and sessile spikelets about ¼ inch long with awns ¼–½ inch long (Fig 43*I*) Little bluestem occupies dry hills, prairies, and open woods of medium elevations in every state except Washington, Oregon, and California and often forms the climax cover It produces a large volume of forage that is grazed with relish while it is young and tender It supplies much pasturage up to midsummer, particularly for cattle and horses The general forage rating is "excellent."

Sorghums (*Sorghum*)

The sorghums are tall, robust annuals or perennials with unbranched culms and long flat leaves The racemes are reduced to one or few joints and borne in large panicles The sorghums are best known for their sweet juice, as in sorgo or saccharine sorghums, and as fodder and hay plants, like Sudan grass, kafir, and milo Late in the season the sorghums sometimes produce cyanogenetic compounds that cause poisoning of grazing animals Johnson grass is the most common perennial pasture species

81 Johnson Grass (*S halepense*) This robust, smooth perennial has extensive, scaly rootstocks and open, reddish or purple panicles, hairy at the base, 6–12 inches long (Fig 43*J*) It is native of the Mediterranean regions and is well represented in the eastern, mid western and southern states, including New Mexico, Arizona, and southern California When young the leafage is palatable and wholesome to all stock. On cultivated land, especially in irrigated areas it is often a troublesome weed although it is a heavy yielder It is perhaps most popular for forage in the cotton belt. In the autumn Johnson grass sometimes causes livestock poisoning, because of the presence of prussic acid (*17, 18, 25*) It produces a large volume of herbage, and its general forage rating is "good"

Indian Grasses (*Sorghastrum*)

These are erect, tall perennials, with auricled sheaths, flat, narrow leaves, terminal panicles of numerous 1- to few-jointed racemes, the sessile spikelet with a bent and twisted awn about ½ inch long, the pediceled spikelet wanting Indian grass is the most important native forage species of this group

82. Indian Grass (*S nutans*) This climax species grows 3–8 feet tall, has short, scaly rhizomes and narrow, dense, yellowish panicles The distribution is from the Atlantic Coast states to Montana, south to Arizona, New Mexico, and Mexico, where it occupies prairies, open woods, and dry slopes It is a common constituent of wild "prairie" hay in the eastern Great Plains region The forage is of exceptionally high quality during the period of rapid growth, and it is also grazed with considerable relish after curing. The general forage rating is "excellent"

Millet Tribe (Paniceae)

The tribe Paniceae has spikelets jointed on the pedicel below the glumes, and 1 terminal, perfect floret, with a staminate or neuter floret below, the fertile lemma being firmer than the glumes

It is a large and important tribe in the tropics and regions of mild climate, as in the southern states The most important forage genera are the panicgrasses, the carpet grasses, and the paspalums (*3, 13*).

Panicums (*Panicum*)

These are annuals or perennials, the pedicels of the spikelets being jointed below the glumes, the entire spikelet falling intact, the first glume is small, the second glume and sterile lemma commonly about equal, the three of like texture and formerly regarded as three glumes *Panicum* is the largest genus of all grasses, and includes more than 500 species, most of which are warm-season growers Some 175 species occur in the United States, with their center of distribution in the Southeast Several species are found in the Southwest. Although of greatest value in the southeastern states, the panics do contribute measurably to the seasonal forage in Arizona, New Mexico, Texas, and Mexico Their palatability varies from almost worthless to good The more robust forms are best utilized by cattle and horses, usually only up to about midsummer Paragrass (*P. purpurascens*), a perennial introduced from South America, has been extensively seeded on ranges from southern Texas to the southeastern seaboard Vine-mesquite

(*P. obtusum*), a stoloniferous species, and bulb panic (*P. bulbosum*), which has culms with bulblike bases, are common in the Southwest and Texas, where they are grazed with moderate gusto by most stock. Hall's panicum (*P. hallii*), which occupies dry to moist ground in Texas and Arizona, produces abundant forage on bottom lands and irrigated fields. The general pasturage rating of panicgrasses is "fair."

83. Switchgrass (*P. virgatum*). This is a species with strong, creeping rhizomes; it occurs in every state east of the Mississippi River and westward to southern Manitoba, eastern Montana, eastern Nevada, Arizona, and western Texas, and southward throughout Mexico. Like most panicgrasses, this species is palatable while young but not highly relished after maturity (*28*).

Carpet Grasses (*Axonopus*)

There are but 3 species of carpet grass in the United States, all inhabiting the humid Southeast.

84. True Carpet Grass (*A. compressus*). This stoloniferous perennial grows 8–24 inches tall, has flat and abruptly pointed leaf blades and slender, somewhat digitate racemes (Fig. 43*K*). It occurs from Florida to southern Louisiana, where it is often abundant on moist muck soils. Its forage rating is "good."

85. Carpet Grass (*A. affinis*). This species, which has narrower leaves and less prominent stolons, occurs from North Carolina to Texas. The forage rating is "good."

Paspalums (*Paspalum*)

These grasses have subsessile, mostly obtuse spikelets which are solitary or in pairs arranged in two rows on one side of a narrow or dilated rachis; the first glume is usually wanting, the second glume and the sterile lemma are of about equal length. Paspalums are most abundant in the Southeast, and in the tropics. Dallis grass (*P. dilatatum*), native of South America, is valuable in dairy regions of the southern states, and in mild climates and moderately moist soils of the West. Smooth paspalum (*P. pubiflorum* var. *glabrum*), a native species, is fairly abundant in some sections from Texas to the southeastern seaboard, where it provides fair to good forage (*28*). Florida paspalum (*P. floridana*), occurring from Kansas and Texas eastward to the coast, is likewise moderately palatable. Vasey grass (*P. urvillei*), another South American species, is palatable to stock and is used for hay in the Southeast. The general rating of the paspalums is "fair."

Comparative Forage Values of the Tribes

The comparative values of the eight tribes considered—based on the over-all rank of the individual numbered grass species discussed in Chapters 8 and 9, are summarized in Table 1. The comparisons are derived by assigning a value of 4 to species rated as excellent, 3 as good, 2 as fair, and 1 as poor.

TABLE 1

COMPARATIVE FORAGE VALUE OF TRIBES, AS INDICATED BY THE SPECIES RATED AS EXCELLENT, GOOD, FAIR, OR POOR

Tribe	*Rating of Species*				*Tribal Rating*	
	Excellent	Good	Fair	Poor	Numerical	General
Oat tribe (Aveneae)	0	6	1	0	20	Fifth
Barley tribe (Hordeae)	3	1	11	0	37	Third
Fescue tribe (Festuceae)	6	12	6	1	73	First
Grama tribe (Chlorideae)	3	3	3	0	27	Fourth
Mesquite tribe (Zoysieae)	2	1	0	0	11	Seventh
Timothy tribe (Agrostideae)	0	10	7	1	45	Second
Sorghum tribe (Andropogoneae)	3	1	0	0	15	Sixth
Millet tribe (Paniceae)	0	2	1	0	8	Eighth

The fescue tribe, with 6 species rated as excellent, 12 as good, 6 as fair, and only 1 as poor, ranks first in importance. It includes such valuable genera as *Poa*, *Festuca*, and *Bromus*, these probably rating in forage contribution in the order named. The timothy tribe, though containing no species in the "excellent" column but having several in the "good" column, is second in importance, *Muhlenbergia*, *Sporobolus*, and *Stipa* being the outstanding genera in native forage production. The barley tribe and the grama tribe rank third and fourth, *Agropyron* being the most important genus of the former, and *Buchloe* and *Bouteloua* of the latter. The oat tribe is seen to be well out ahead of those of moderate rank in the West. Other workers might conceivably reverse the rating of some of the tribes, however, the species of the first four tribes will presumably continue to enlist the chief interest of the grass breeder and the range manager.

The Grasslike Plants

The sedges (*Carex* spp.)—members of the sedge family (Cyperaceae)—and rushes (*Juncus* spp. and *Juncoides* spp.)—genera of the rush family (Juncaceae)—are popularly termed "grasslike" plants, because of their resemblance to grasses. Seasonally, they provide considerable

forage of fair to good nutrition for livestock, especially cattle and horses and for wildlife (*23*). Since more species of these plants grow in marshes and wet meadows than in dry sites, they are most extensively grazed in summer and autumn when the soil is moderately dry.

It is important to distinguish between the genera of grasslike plants and those of the grasses, since they differ both ecologically and economically.

Distinctions Between Grasslike Plants and Grasses

Sedges may be distinguished from grasses in the following ways (*21*):

1. The stems of sedges are triangular, jointless, and solid, the leaves 3 ranked, and the leaf sheaths closed.
2. The stems of grasses are generally hollow, cylindrical, and jointed, the leaves 2 ranked, and the leaf sheaths usually split.

Rushes (*Juncus* and *Juncoides*) are readily distinguished from grasses and sedges:

1. The flowers of rushes are regular and, though diminutive, similar in form to those of a lily, having a perianth composed of six bractlike scales and 3 to many small seeds borne in a capsule or small pod.
2. The flowers of grasses and sedges are not symmetrical, the perianth being irregular and inconspicuous or obsolete, and are subtended by husklike scales, each flower producing but a single seed.

Species of Grasslike Plants

Sedges (*Carex*)

The sedges, numbering 1000 or more species, compose one of the largest genera of flowering plants in the world. In addition to providing forage, the rootstocks or rhizomes and fibrous roots afford effective soil protection against erosion. Two representative species are discussed here.

Threadleaf Sedge (*C. filifolia*). This sedge, also called niggerwool (Fig. 44*A*), ranges from Texas and California to the Yukon Territory and Saskatchewan, between elevations of 3000 to 12,000 feet. It commonly occupies open, well-drained grassland and moist, open timber areas. The forage value varies from fair to more generally good for all stock, being of highest value early in the season. The stout, fibrous roots endure heavy trampling, and the species is fairly resistant to drought (*6*). The general forage value rating is "good."

Ovalhead Sedge (*C. festivella*). Ovalhead sedge occurs rather commonly, but seldom in pure stand, between elevations of 6500 to 12,000 feet from New Mexico westward to the Sierra Nevada of California, and northward to Alberta. It favors moist, open meadows and hillsides

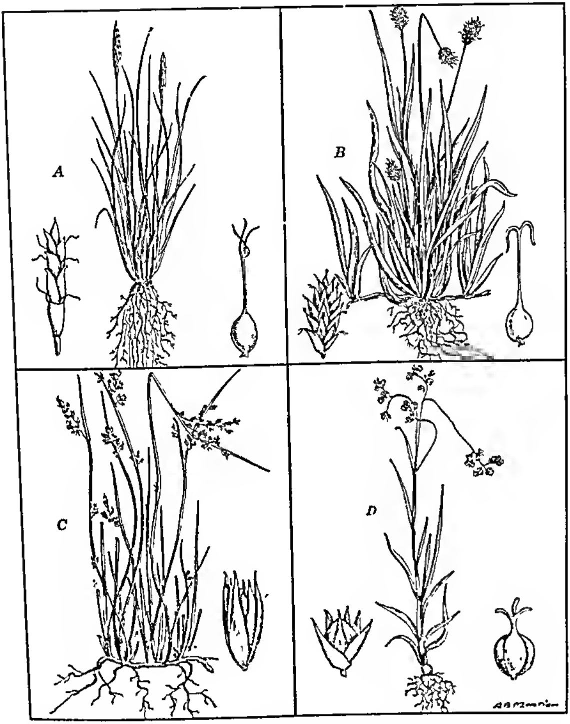

FIG. 44. *A*, Threadleaf sedge (*Carex filifolia*); left, staminate spike; right, achene. *B*, Ovalhead sedge (*Carex festivella*); left, the pistillate spike, right, an achene. *C*, Wire rush (*Juncus balticus*), showing perianth and capsule. *D*, Millet woodrush (*Juncoides parviflorum*); left, the perianth, right, the capsule.

and avoids waterlogged areas Sheep are fond of the fine, tender, bright green herbage but it is sought more eagerly by cattle and horses throughout the growing season Reproduction is largely from achenes (seed) since the short rootstocks do not give rise to new shoots remote from the parent plant (Fig 44*B*) Continuous close grazing soon destroys the stand Although its palatability varies somewhat according to locality the general forage rating is "good"

Rushes (*Juncus* and *Juncoides*)

Juncus, with about 215 species, is the largest genus of the rush family (Juncaceae), *Juncoides*, the only other genus of the family, embraces some 65 species They are mostly perennial plants and are chiefly found in wet meadows and swamps

As forage, they rank from fair for sheep to fair to good for cattle and horses Elk are seasonally fond of several species

Wire Rush (*Juncus balticus*) Among the most common species of *Juncus* is wire rush, whose various races range from Newfoundland and Labrador to Alaska, California, New Mexico, Missouri, Nebraska, and Pennsylvania (Fig 44*C*) The elevation ranges from sea level, through valleys and deserts, to near timberline It occupies various soil types preferably of high moisture content, and is a common component of meadow hay, especially in Colorado The forage value is variable, but it is utilized best by cattle and horses early in the season Pure stands are cropped lightly, but covers composed of some 25 percent of wire rush are grazed fairly close by cattle, horses, and sheep (*6*) The elaborate root system and numerous rootstocks account for the tenacity of wire rush on closely grazed areas and for its usefulness in soil protection The over all forage rank is "fair

Millet Woodrush (*Juncoides parviflorum*) Woodrushes (*Juncoides*) differ from rushes (*Juncus*) in that the capsule (seed vessel) of *Juncoides* bears 3 seeds whereas in *Juncus* the capsule is many seeded, also in *Juncoides* the leaves are softer and flatter, and the culms are hollow and more leafy

Millet woodrush is fairly typical in growth habit and forage value of the genus (Fig 44*D*) It grows in low, wet woods and open, moist meadows from Alaska to Labrador, thence to New York, Minnesota New Mexico, and California occurring in the mountains of the western states Tufted hairgrass and species of sedges are common associates The herbage is grazed more extensively by cattle than by sheep because of the miry habitats to which it is largely confined The palatability is perhaps highest in autumn, since the leafage tends to remain green and tender when associated plants have matured The slender rootstocks

afford protection from injury by trampling. The general forage rating is "fair."

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Chapter 10

IMPORTANT WESTERN FORBS AND SHRUBS AS STOCK-FOOD PLANTS

In this chapter we will briefly discuss the more palatable and useful forbs and browse plants of the West. Whereas grasses contribute much of the natural western range forage, domestic livestock and big game animals feed extensively on browse in winter and on browse, forbs, and grass at other seasons (*12*).

Forbs and Shrubs as Pasture Plants

Forbs—sometimes called weeds—are relatively low-growing, non-grasslike annual or perennial broad-leaved plants, the herbaceous top growth of which dies back to the ground each autumn. Forbs such as the clovers, filaree, dandelion, and cow parsnip contribute in no small way to the hay and pasture crops. But forbs are less valuable than the grasses for the following reasons: (1) they seldom occur in dense stand; (2) few species cure well on the root; hence they provide little feed after maturity; (3) they are more readily injured by grazing than grasses; (4) many species are poisonous; (5) few are climax in the stand and often are replaced by grasses and other plants; (6) they provide less protection to the soil than grasses. Even so, the presence of palatable forbs is an asset to any range.

Browse, the other group discussed here, includes woody deciduous or nondeciduous shrubs or trees, the sprouts, twigs, stems, vines, and leaves of which are cropped by livestock and wildlife. Browse plants occur at all elevations and life zones but are most abundant in desert regions, particularly on alkaline or saline soils (*2, 4*). Such common shrubs as deerbrush, bitterbrush, ceanothus, saltbushes, serviceberry, and winterfat are highly regarded browse plants of mountains and lowlands. The seasonal nutritive value, especially of the nondeciduous browse species, tends to vary less than in grasses and forbs (*12, 8*). This fact accounts for the generally satisfactory condition of stock maintained largely upon browse range in winter.

Rating of the proper use or palatability of browse plants is based on

22 Sampson, A. W. 1919. "Plant Succession in Relation to Range Management." *U. S. Dept. Agr. Bull.* 791: 1–76.

23 Sampson, A. W. 1924. *Native American Forage Plants.* John Wiley & Sons, Inc., New York. 435 pp.

24 Sampson, A. W., A. Chase, and D. W. Hedrick. 1951. "Range Grasses of California." *Calif. Agr. Expt. Sta. Bull.* 724: 1–131.

25 Sampson, A. W., and H. E. Malmsten. 1935. (Revised 1947.) "Stock Poisoning Plants of California." *Calif. Agr. Expt. Sta. Bull.* 593: 1–90.

26 U. S. Department of Agriculture. 1948. *Grass. 1948 Yearbook of Agriculture.* 892 pp.

27 Vasey, G. 1889. "The Agricultural Grasses and Forage Plants of the United States." *U. S. Dept. Agr., Botan. Dv., Special Bull.* 148 pp.

28 Walker, A. H. 1950. "Know your Grasses." *Texas Agr. Ext. Service B.* 182: 1–63.

29 Wooton, E. O., and P. C. Standley. 1912. "The Grasses and Grasslike Plants of New Mexico." *N. M. Agr. Expt. Sta. Bull.* 81: 1–175.

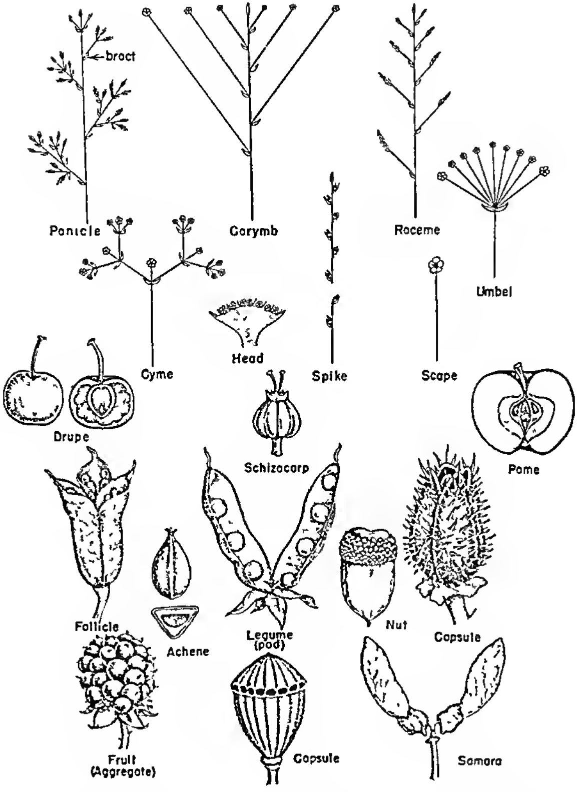

FIG. 45. The eight upper diagrams show arrangements of the more common forms of inflorescences, and the lower ones portray the fruits of many common forbs and browse plants. Note the means of dehiscence of some of the fruits

the accepted concept of the degree to which the herbage within easy reach of stock is grazed when the range is properly utilized. These ratings as here set up are sufficiently broad to be readily applicable: excellent, 80 and higher, good, 60 to 80, fair, 40 to 60, poor, 40 and lower.

The many thousands of forb species which contribute to the range forage clearly exceed those of the grasses. When the numbers of browse species—totaling several hundred—are included, these two groups far outnumber the grasses. On most western ranges a scattered stand of palatable forbs and browse plants is desirable, because they add variety to the diet and commonly enhance the nutritional intake of livestock and wildlife. On predominantly grass range, on the other hand, suitable management should prevent conspicuous replacement of the grass by forbs and brush plants. Selective, close grazing by cattle, since they largely prefer the grasses, favors invasions of forbs, browse, and unpalatable shrubs; grazing by sheep or goats, since they prefer forbs and browse to grass, favors invasions of the grass cover. Conservative grazing by both cattle and sheep, where a combination range of grass, forbs, and browse justifies it, helps to maintain a desirable balance among these plant groups.

Since reference will occasionally be made to the nature of the inflorescence and fruit peculiar to the different species discussed here, the more common of these characteristics are shown in Fig. 45.

The forb and browse plants are here discussed under the families to which they belong. Although the plants that have some food value belong to many different families, the more palatable, wholesome, and widely distributed species are included in but a few families. Six families embrace most of the forbs, and nine families comprise the outstanding browse plants on the western range. These are:

Important Forb Families

- Pea or legume family (Leguminosae)
- Carrot or parsley family (Umbelliferae)
- Geranium family (Geraniaceae)
- Sunflower or composite family (Compositae)
- Borage family (Boraginaceae)
- Primrose family (Onagraceae)

Important Browse Families

- Pea or legume family (Leguminosae)
- Beet or saltbush family (Chenopodiaceae)
- Rose family (Rosaceae)
- Sunflower or composite family (Compositae)
- Buckthorn family (Rhamnaceae)
- Willow family (Salicaceae)
- Honeysuckle family (Caprifoliaceae)
- Gooseberry family (Grossulariaceae)
- Oak or beech family (Fagaceae)

FIG. 46. *A*, Rydberg clover (*Trifolium rydbergii*); *B*, California bur-clover (*Medicago hispida*); *C*, Spanish clover (*Lotus americana*); *D*, mountain lupine (*Lupinus alpestris*); *E*, aspen peavine (*Lathyrus leucanthus*); *a* and *b*, style branches of *Lathyrus* and *Vicia*, respectively; *F*, mesquite (*Prosopis juliflora* var. *glandulosa*).

Most peavines are palatable to stock, but their seasonal palatability varies greatly. Some are taken throughout the season, others only after the flowers appear, still others not until the first frosts come in the autumn. They are sought most by sheep, but cattle and game animals also feed upon them. Their general forage rating is "good."

The vetches are probably best known for the green manure and hay values of the cultivated forms. On the range, American vetch (*V. americana*) is a widely distributed and fairly typical species. It is palatable to all livestock and to big game animals. It endures shade well, but the stand is usually scattered, hence the volume of forage produced is not especially large. The forage value of this plant, and for the genus as a whole, is "good."

Browse of the Pea or Legume Family (Leguminosae)

The browse plants of the pea family are of much less importance than the forbs. In the Southwest several genera contribute to the range food supply, but only 4 warrant consideration.

Mesquites (*Prosopis* spp.) and Screwbean (*Strombocarpa odorata*)

One or more of these closely related species occurs from eastern Texas and southern Kansas to southern and Lower California and south into Mexico. The tender spring leafage and twigs are cropped by all stock to a limited extent. They produce their most valuable feed in late summer when the abundant, large, sweet, pulpy clusters of seed pods have formed. The pods are highly palatable and nutritious. Mesquite (*P. juliflora* var. *glandulosa*) (Fig. 46F) and screwbean are essentially identical as food plants, the overall rating being "poor." These plants are aggressive invaders of range lands, partly because the seeds pass uninjured through animals. In many instances the stands have become so dense as markedly to lower the grazing capacity. Various methods of controlling these invasions are under investigation (Chapter 13).

Catclaw (*Acacia greggii*)

Some 16 species of the genus *Acacia* are native to western United States and are most abundant in desert and semidesert areas of the Southwest and Mexico. Although most acacias have some value, catclaw is the best food plant. It occurs from western Texas to southern Nevada and south into Mexico. The palatability is not high, but the current growth is utilized more in dry years when other feed is scarce. The twigs green up early in the spring and are cropped to a limited extent at that season. On well managed range catclaw is only lightly

summer. Even under close grazing or periodic burning of the cover, California bur-clover seems to thrive (*10*). Its forage rating is "excellent."

Deer Vetches (*Lotus* spp.)

These are mostly annual or perennial forbs, a few being half-shrubs. They occur over a wide geographical range in the West at low to intermediate elevations, some occupying meadows and streambanks, others occurring on the drier foothills, freshly burned woodlands, and brushy areas. The most distinctive generic characteristics are the pinnately compound leaves and the flowers like those of the pea, which range in color from white and pink to yellow.

The forage values of deer-vetches range from high to low. They usually grow in scattered stand, hence they make up but a small part of the forage. Spanish clover (*L. americana*), a widely distributed annual, is characteristic of the more palatable species (Fig. 46C). It is sought by all stock throughout the growing season, has strong seed habits, and produces a fair volume of herbage. Its forage rating is "good."

Lupines (*Lupinus* spp.)

The western range country supports many species of lupine. They are annual or perennial plants and have alternate, palmately compound leaves and showy blue, purple, or sometimes pink, white, or yellow racemes of flowers. A few species are woody.

The forage value of many lupine species is doubtful. Some rank fairly high as food plants, others are poisonous, particularly after the pods are formed, hence it is not logical to assign a specific palatability rating to the genus.

Mountain lupine (*L. alpestris*), a fairly typical perennial of wide distribution in foothills and mountains of the West, is rather highly palatable up to midsummer to cattle and sheep but not to horses (Fig. 46D). Like many lupines, it grows best in a mixed grass-and-herb cover and in open woodland. Its forage rating is "fair."

Peavines (*Lathyrus* spp.) and Vetches (*Vicia* spp.)

These occupy wooded areas of wide elevational range in the West. Aspen peavine (*L. leucanthus*) is typical (Fig. 46E). Peavines and vetches are structurally similar, having alternate, compound leaves which commonly terminate in tendrils, but are readily distinguished by the flower styles. In *Lathyrus*, hairs occur only on the side next to the stamens; in *Vicia*, hairs completely encircle the style (Fig. 46E, *a*, *b*).

plant in the Rocky Mountains from Utah and Colorado northward. Sheep take the leafage closely, and it is fair-to-good feed for cattle and game animals. Its over-all forage rating—and that for the genus—is "good."

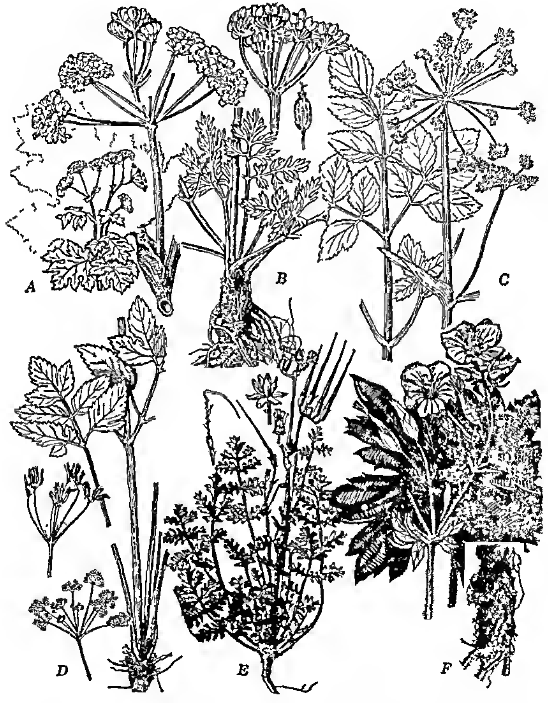

FIG. 47. *A*, Cow parsnip (*Heracleum lanatum*); *B*, fernleaf wild celery (*Ligusticum filicinum*); *C*, Lyall angelica (*Angelica lyallii*), *D*, sweet-anise (*Osmorrhiza occidentalis*); *E*, red-stem filaree (*Erodium cicutarium*); *F*, sticky geranium (*Geranium viscosissimum*).

browsed, close browsing indicates that the better forage of the area is overutilized Its over all pasture rating is 'poor'

Mimosas (*Mimosa* spp)

Three species of mimosa—catclaw mimosa (*M biuncifera*), fragrant mimosa (*M fragrans*), and velvet mimosa (*M dysocarpa*)—occur commonly on semidesert areas from western Texas to southern Arizona and south into Mexico Although utilization is hampered by the thorny branches and tangled growth, these plants rank as 'fair' in winter and spring and are cropped moderately at all seasons during periods of prolonged drought Velvet mimosa is of less value than the other two

Carrot or Parsley Family (Umbelliferae)

These strongly scented forbs are common on the western range Their flowers are borne mostly in simple or compound umbels (Fig 47) Parsnip carrot, and parsley are familiar cultivated plants of this family

Some of the native species, like waterhemlock and poisonhemlock, are poisonous, but many others provide good range feed The best forage plants of this family are cow parsnips wild celery, angelica and sweet cicely

Cow Parsnip (*Heracleum lanatum*)

Cow parsnip is by far the most important range food plant of the genus *Heracleum* (Fig 47*A*) It is a moisture loving perennial and grows best in open woodlands over much of the western country Its elevational range is from sea level to about 10 000 feet.

Although cow parsnip seldom forms in dense stands, its produces abundant forage due to its large size and profuse leafage It is highly palatable to all stock, especially in the early stages of growth when even the succulent stems may be cropped to the ground The general forage value is 'good'

Wild Celeries or Loveroots (*Ligusticum* spp)

There are 18 species of wild celeries in the United States, all perennials They are typically mountain plants, and they form a scattered growth in moist woodland, meadows, and fertile sites to above 12 000 feet in elevation

Most wild celeries are palatable to livestock and game animals throughout the growing season some being choice feed for sheep, goats deer, and elk and fair for cattle and horses (*16*) Fernleaf wild celery (*L filicinum*) is one of the better species (Fig 47*B*) It is a common

maintenance except to discourage competition from taller vegetation. Filarees are among the first herbs to invade denuded or overgrazed areas and tend to increase where the grass cover is closely cropped. Conspicuous increase in filaree is usually an indication of overgrazing.

Red-stem filaree (*E. cicutarium*), a European species, has the widest distribution and is the one that stockmen commonly refer to when speaking of these plants (*24*). The pinnate-compound leaves, the deeply cleft leaflets, and the reddish stems distinguish it from the other species (Fig. 47*E*). In favorite habitats it produces a large portion of the total forage from February to May, after which the leafage dries up. Its nutritive value is high when the plant is green, and it has a desirable balance in crude protein, calcium, and phosphorus even after maturity (*8, 9*); accordingly, strong healthy bone in growing animals is developed on red-stem filaree range (*23*). Range stock and big game animals feed upon it from the time the rosettes are formed in February until the last remnants of the discolored, dry, and broken stems and the matted bunches of tailed seeds cease to be available. Because of their capacity for close grazing, sheep make the best use of this plant. A combination of filaree, grass, and wholesome browse, as in the desert in good seasons, is unexcelled during spring lambing. One disadvantage of any filaree range, however, is that some seeds get into the wool, thereby decreasing its sale price. This drawback can be minimized by shearing twice annually. The forage value of red-stem filaree is excellent for sheep and good for other range livestock and for wildlife, the over-all rating being "good" to "excellent."

Geraniums (*Geranium*)

There are some 16 species of geraniums, mostly perennials, occurring natively on the western range, in addition to a few introduced species. They grow mostly in the mountains up to 10,000 feet in elevation, on grasslands and wooded areas.

Geraniums are cropped most closely by sheep and deer, cattle taking only the more tender, young foliage. Sticky geranium (*Geranium viscosissimum*) is representative of the better forage species (Fig. 47*F*). It ranges from Colorado to California and northward into Canada between elevations of 5000 and 10,000 feet. The herbage is "fair" to "good" for sheep, and "poor" to "fair" for cattle, the over-all rating being "fair."

Forbs of the Sunflower or Composite Family (Compositae)

This is the largest family of the flowering plants, numbering more than 13,000 herbs and shrubs. Many palatable range plants and some

ANGELICAS (*Angelica* spp.)

The angelicas are moderately tall erect herbs with fleshy roots. They occupy fairly rich moist soils in the mountains throughout the West, where they grow in scattered stands.

Lyall angelica (*Angelica lyallii*) is among the more widely distributed species occurring in the mountains from Utah and western Montana to northern California and north into British Columbia (Fig. 47C). The herbage is highly palatable to sheep and goats and is cropped moderately by cattle and big game. Its general forage rating is good.

SWEET CICELIES (*Osmorrhiza* spp.)

Members of the genus *Osmorrhiza* have thick aromatic perennial roots, linear-oblong fruits, and mostly basal leaves (Fig. 47D). Most species are highly palatable to all stock and to big game animals.

One of the most widely distributed species is sweet anise or western cicely (*O. occidentalis*). It is a mountain plant, occurring from Alberta to Colorado, California, and British Columbia between elevations of 2000 to 10 000 feet. The herbage is widely sought by sheep and when green is moderately relished by cattle, horses, deer, and elk, but it is useless as feed when the herbage has matured or has been killed by frost. Its general forage rating is good.

Geranium Family (Geraniaceae)

The geranium family accounts for a large volume of forage even though it embraces only 12 genera. Most of the forage is contributed by two genera, the filarees and the geraniums.

ALFILERIAS OR FILAREES (*Erodium* spp.)

The alfilerias, more commonly called filarees by some stockmen and storksbill by others, are annual forbs. The leaves are opposite and commonly grow in a rosette or leaf tuft, and the fruit consists of five 1-seeded carpels bearing spirally coiled, taillike styles (3). The genus consists of some 60 species, most of which are indigenous to the Mediterranean region.

The filarees are most important as forage in the valleys and foothills of California and the Southwest. They occur from sea level to about 4500 feet in elevation and occupy relatively dry to well-drained soils. The conditions most congenial to their growth are (1) mild winter temperature, (2) winter precipitation, (3) soils that are not strongly alkaline, and (4) limited competition with other vegetation (23). Once established in a region, they require no special treatment to insure their

Fig. 48. *A*, yarrow (*Achillea lanulosa*), *B*, smooth mountain dandelion (*Agoseris glauca*), *C*, arrowleaf balsamroot (*Balsamorhiza sagittata*), *D*, arrowleaf butterweed (*Senecio triangularis*), *E*, mules-ears (*Wyethia amplexicaulis*), *F*, niggerhead (*Rudbeckia occidentalis*)

poisonous ones belong to this family Lettuce artichoke, and dandelion are well known plants of this group

The most characteristic feature of the composite family is the crowding together of the flowers in heads borne on an enlarged summit of the receptacle and surrounded by bracts

On the whole the species do not rank high in palatability, but because of their abundance they contribute a large volume of range feed

Yarrow (*Achillea* spp)

These aromatic perennials with finely dissected leaves are widely distributed over the western range from sea level to timberline where they grow in scattered stand in a variety of habitats

The forage value of these plants varies greatly Western yarrow (*A lanulosa*) a representative species (Fig 48*A*) is cropped moderately throughout the season by livestock and game animals on some ranges whereas in other localities it is grazed but little In the Wasatch Mountains of Utah western yarrow was noted to increase markedly on some overgrazed range (*6*) Its forage value rates as 'fair

Smooth Mountain Dandelion (*Agoseris glauca*)

Smooth mountain dandelion, including its several varieties is a perennial that inhabits open sites from the ponderosa pine forest well into subalpine areas (Fig 48*B*) Although never forming the dominant vegetation it is an important constituent of the forage because of the rather large volume of leafage produced per plant and its high palatability especially for sheep Even under conservative grazing sheep will keep the herbage cropped back near the ground surface Cattle horses and wildlife also crop the leafage and flower stalks with considerable relish The over all rating is good

Balsamroot (*Balsamorhiza* spp)

The name balsamroot refers to the thickened perennial resinous taproot common to the western species They occur most commonly on dry open flats, woodlands and open forests

Arrowleaf balsamroot (*B sagittata*) is fairly typical of the forage value of the group (Fig 48C) It is a widely distributed species and an important constituent of the forage on spring range where it is fairly palatable to all stock The flower heads are choice feed and the green leafage is cropped with considerable gusto by livestock, deer and elk The over all forage value is good

Shrubs of the Sunflower or Composite Family (Compositae)

The composite family contains no outstanding browse species Indeed, only one genus—the sagebrushes—warrant full discussion

Big Sagebrush (*Artemisia tridentata*)

The sagebrushes are relatively important browse plants Big sagebrush, also called black sage, is among the most widespread and abundant of shrubs in the West It is an erect, nondeciduous and many-branched plant 3–6 feet high, the grayish leaves being mostly 3-toothed at the tip and distinctly aromatic (Fig 49*A*) It is confined to semiarid regions from western Nebraska to Montana, British Columbia, eastern California, Lower California, and northern New Mexico, and it is especially characteristic in the Great Basin region The elevation range is between 1500 and 9000 feet

The palatability of big sagebrush is moderate to negligible On summer and early fall range it is not browsed and is even a pest, but on winter desert range it is often the mainstay ration for sheep in late fall, winter, and early spring The current twigs, persistent leaves, and fruiting heads are cropped more or less in proportion to the presence of other feed During prolonged winter storms big sagebrush sometimes provides the only feed available Cattle also browse upon the current growth to a considerable extent in winter, and horses feed upon it limitedly It is also utilized by game animals The plant is cropped less in its northern range than in the Southwest (*16*) Chemical studies indicate that its nutritive value is well balanced and satisfactory, indeed, it seems to have tonic properties for livestock (2). The general browse value of big sagebrush is "fair" to "good"

In many localities overgrazing has caused invasions of big sagebrush into former grasslands, thus sharply decreasing their grazing capacity. A program of plowing, burning, and spraying with toxic herbicides of such infested areas, followed by reseeding to suitable grasses, is now being attempted with apparent success on the better sites

Fringed Sagebrush (*Artemisia frigida*)

This many-branched half-shrub grows 12–24 inches high and has silvery-hairy leaves (Fig 49*B*). In the Southwest it is known as estafiata and farther north as pasture sagebrush Its distribution is probably the widest of all the sagebrushes, since it occurs through a large part of western United States and into Mexico, where it inhabits deserts, valleys, mesas, and mountains

Partly because of its diverse habitats, the browse value varies widely,

Groundsels (*Senecio* spp.)

The groundsels, also called butterweeds and ragworts, constitute the largest genus of the flowering plants, with some 2600 species, of which possibly 200 occur in North America. They occupy a great variety of habitats from sea level to timberline, and the different species vary greatly in forage value. Some are of low palatability, a few are poisonous, still others are cropped with relish, especially by sheep and wildlife.

Arrowleaf butterweed (*S. triangularis*) is one of the more useful species (Fig. 48*D*). It grows in moist sites from Colorado to California and northward to Alaska up to about 9000 feet in elevation. Early in the season sheep devour both leaves and stems, but later only the leafage is eaten. The plant is rated as "good" for sheep and "fair" to "poor" for cattle, the over-all rating being "fair."

Mule's-Ears (*Wyethia amplexicaulis*)

Mule's-ears, a perennial 1–2 feet tall, with heavy taproot and with leaves shaped like the ears of a mule, is the most widespread and valuable of the genus *Wyethia* (Fig. 48*E*). It occurs in the sagebrush-grass association and in open forest up to 9000 feet in elevation. Sheep, deer, and elk eat the young leaves and often crop the tender center of the clump closely, but cattle seldom devour all the leafage. The flower heads are highly relished by all grazing animals. The over-all forage rating is "good."

Niggerhead (*Rudbeckia occidentalis*)

This coarse, tall herb, also called western coneflower, is readily recognized by the rayless, dark, cone-shaped flower heads (Fig. 48*F*). It occupies moist sites and is most abundant at intermediate elevations in the Wasatch Mountains of Utah. The flowers and young leafage are taken best by sheep, the over-all forage value being "fair."

Other Composite Forbs

Among other useful range forbs of the composite family are the dandelions (*Taraxacum* spp.), the hawkweeds (*Hieracium* spp.), hawksbeards (*Crepis* spp.), and little sunflower (*Helianthella* spp.). The more important species of these genera occur in scattered stand over much of the western foothill and mountain range. They are essentially "fillers," adding variety to the diet but contributing only little to the forage crop. The domesticated sunflower (*Helianthus annuus*) is sometimes grown for silage.

but it is regarded as one of the better sagebrush food plants (*4*). In most localities it is rated as good sheep and goat feed, fair to good for cattle, and fair for deer and elk. It is most useful on the desert ranges of the Southwest. In the Northwest, fringed sagebrush has invaded extensive grasslands and is regarded as a good indicator of overgrazing, since it is practically worthless as forage in that region. Its over all forage rating is "fair."

RABBITBRUSHES (*Chrysothamnus* spp.)

Rabbitbrushes are widely distributed in western North America and sometimes compose much of the stand. Few are palatable to stock. Those cropped most, but never closely, by cattle and sheep are lanceleaf yellowbrush (*C. lanceolatus*) and twistleaf rabbitbrush (*C. viscidiflorus tortifolius*), growing at intermediate to high elevation. Small rabbitbrush (*C. stenophyllus*), a desert species, furnishes a fair amount of feed for sheep in the winter (*4*). Rubber rabbitbrush (*C. nauseosus*) and, in some localities, lanceleaf yellowbrush are useful indicators of range depletion (*19*).

Borage Family (Boraginaceae)

All species of the borage family are herbs. Only one genus—*Mertensia*—contains plants of much importance on the range. Several of these perennials are highly palatable to stock and game, but some have little or no forage value.

MOUNTAIN BLUEBELLS (*Mertensia ciliata*)

Mountain bluebells represents the leafier, larger, and better forage species of the group (Fig. 49C). Its distribution is from eastern Oregon and western Montana to Nevada and Colorado, between elevations of 5000 and 12,000 feet. Sheltered places of fertile, moist soil are the favored habitats.

The palatability of mountain bluebells is high for deer and sheep, sheep often grazing the plants down to the crowns, and the plant is moderately cropped by cattle and horses. Its over-all forage rating is "good."

Evening Primrose Family (Onagraceae)

The plants of this family are annual or perennial herbs. Of these, fireweed is much the best range food plant.

FIREWEED (*Epilobium angustifolium*)

This is an aggressive perennial with alternate entire leaves and showy lilac purple flowers borne in terminal racemes (Fig. 49D). Its distribu-

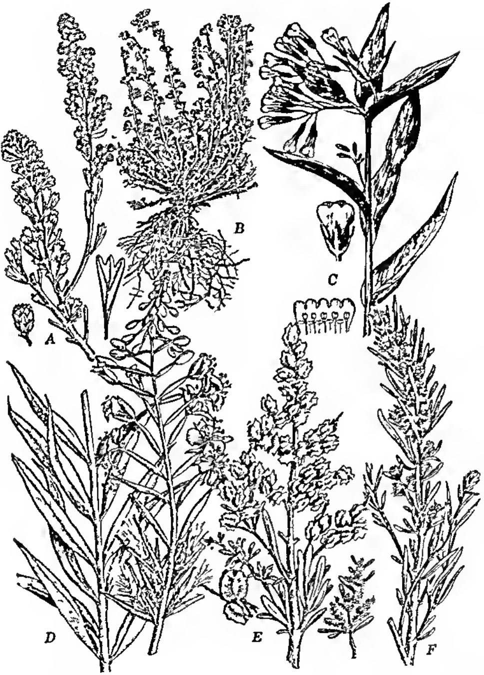

FIG 49 *A*, Big sagebrush (*Artemisia tridentata*), *B*, fringed sagebrush (*A frigida*), *C*, mountain bluebell (*Mertensia ciliata*), *D*, fireweed (*Epilobium angustifolium*), *E*, fourwing saltbush (*Atriplex canescens*), *F*, winterfat (*Eurotia lanata*).

Washington (Fig. 49*F*). Best stands are found in dry, moderately alkaline or saline soils of the lower foothills, plains, and valleys.

Winterfat is one of the more outstanding browse plants on the western range. The tender, leafy stems are cropped with excellent results by all domestic stock and by deer and elk. In many localities winterfat has been thinned out as a result of too close browsing; however, it revegetates quickly under favorable management. Its general forage rank is "excellent."

Rose Family (Rosaceae)

The rose family includes a large number of herbs, shrubs, and trees. Because of the many highly palatable and abundant browse plants of this family it probably ranks first in the category of useful woody species. Familiar foothill and mountain genera are the mountain-mahoganies, roses, and bitterbrush.

Mountain-Mahoganies (*Cercocarpus* spp.)

The 19 species of this genus are half-evergreen shrubs or small trees. They inhabit moderately dry, mountainous regions where they provide a large amount of high-quality browse for livestock and game. The broad-leaved species are generally more palatable than the narrow and thick-leaved forms. True mountain-mahogany (*C. montanus*) is representative of the better broad-leaved group (Fig. 50*A*).

This species occurs from northern California and Oregon to Montana, South Dakota, and New Mexico, on dry ridges and open woodlands between elevations of about 4000 and 10,000 feet. It is a highly important browse plant, the leaves and twigs being taken eagerly by sheep, goats, deer, and elk. Cattle also relish this feed. Game animals browse upon this plant yearlong. Because of its high palatability, overgrazing must be avoided lest the stand be thinned out. The over-all browse value is "excellent."

Roses (*Rosa* spp.)

Roses, both native and cultivated, are probably the most familiar group of the rose family. Wild roses occur commonly on the western range, usually at low to intermediate elevations in scattered stands on diversified sites.

Rose plants are browsed rather closely by sheep and goats but only lightly by cattle. Deer and elk also crop them, sometimes closely to severely, notably in the winter. Among these, Fendler rose (*Rosa fendleri*), although it has rather thorny branches, is typical of the more widely sought species (Fig. 50*B*). It occurs from Montana and

tion is across the North American continent from the Canadian border south into California, New Mexico, and North Carolina. The elevational range is from sea level to as high as 11,000 feet in the Rocky Mountains. In some sites it makes up much of the stand.

In some localities fireweed contributes abundantly to the forage crop. In Oregon, Nevada, and Utah, especially, sheep feed closely upon this plant, and it is moderately palatable to cattle, horses, deer, and elk (*16, 18*). Burning often results in conspicuous temporary increase in fireweed, hence its name. Its over-all forage rating is "good."

Saltbush Family (Chenopodiaceae)

This is a family of herbs and shrubs that are most abundant on alkaline or saline soils. The plants usually have a salty taste which partly accounts for their high palatability. Two genera of half-shrubs—*Atriplex* and *Eurotia*—embrace by far the most imporant food plants of this family and are essentially confined to the winter (desert) range.

Saltbushes and Shadscales (*Atriplex* spp.)

Some members of this genus are surpassed by no other browse plants in volume of feed produced and usefulness as winter pasturage (*1, 2*). Fourwing saltbush (*A. canescens*) is selected to represent this group here.

Fourwing saltbush is a grayish-white, scurfy shrub 1–8 feet high, with numerous, leafy, lax branches (Fig. 49*E*). It ranges from Wyoming and South Dakota to western Texas, California, Nevada, and Utah, where it occupies dry, moderately alkaline or saline areas at low to intermediate elevations. It is one of the most abundant and useful browse plants on the deserts of southwestern and intermountain regions. In winter all livestock and deer eat with gusto the entire plant, including the seed. Because of its high palatability and the fact that the stems are brittle and easily broken by eager animals, the stand is subject to injury from overgrazing. Chemical studies of fourwing saltbush have shown its high nutritive value (*9*). Its over-all feed value is "excellent."

Other native species that are widely distributed and of fairly high rank as feed are shadscale (*A. confertifolia*), Nuttall saltbush (*A. nuttallii*), and Australian saltbush (*A. semibaccata*) which is an Australian introduction and grows naturally along the southern coast of California and a few other places, where it has some feed value.

Winterfat (*Eurotia lanata*)

This multibranched, low shrub is widely distributed from western Texas to western Nebraska and Manitoba westward to California and

South Dakota to Arizona and western Texas into Mexico. The general forage value of Fendler rose, and of roses generally, is "fair."

Cliff Rose (*Cowania stansburiana*)

This is a leafy, stiff stemmed shrub or small tree (Fig. 50C). It occurs from New Mexico and southern Colorado to Utah and California in woodland and ponderosa pine forest between elevations of 4000 to 8000 feet. Where cliff rose is abundant, which it is only occasionally, it provides a large volume of good quality browse for cattle, sheep, and deer from late summer through the winter. The branches are so brittle, however, that close utilization may severely damage the plants. Conservative browsing, on the other hand, induces growth of many leafy lateral branches and results in a larger volume of feed than on underutilized range. The over-all forage value of cliff rose is "fair."

Bitterbrush (*Purshia tridentata*)

This shrub grows from 1½–6 feet high and has many short, strong, and leafy branches (Fig. 50D). It is widely distributed, ranging from Montana to New Mexico, California, and British Columbia, where it occupies arid plains and mountain slopes within the aspen, ponderosa, and piñon belts up to 9000 feet in elevation.

In most localities bitterbrush is grazed with relish the year through, but it is cropped most closely in spring, late fall, and winter. The herbage is of high quality for cattle, sheep, deer, and elk. Wildlife rely on this plant in a large measure for winter feed. Dixon (*5*) reported bitterbrush to be of primary importance to mule deer. Hormay (*11*) and Forsling and Storm (7) concluded that too close cropping is inimical to bitterbrush stands, and they proposed that enough of the current growth be left ungrazed to maintain these plants in strong physiological vigor (Chapter 17). The food value rating of bitterbrush is "excellent."

Serviceberries (*Amelanchier* spp.)

The serviceberries are shrubs or small trees with simple, deciduous leaves, showy white flowers, and berry like fruit. They rank among the more highly esteemed genera for goats, as good to fair feed for sheep, and of moderate value for cattle.

Common serviceberry (*A. alnifolia*) is the most widely distributed on the western range of the 24 species of this group (Fig. 50E). Common serviceberry occurs over a large part of southern Canada to Minnesota, the Dakotas, New Mexico, and California northward to

FIG 50 *A* True mountain mahogany (*Cercocarpus montanus*) *B* Fendler rose (*Rosa fendleri*), *C* cliff rose (*Cowania stansburiana*) *D* bitterbrush (*Purshia tridentata*) *E*, common serviceberry (*Amelanchier alnifolia*) *F* right branch of chamise (*Adenostoma fasciculatum*) left a crown showing profuse sprouting of chamise after burning

Buckthorn Family (Rhamnaceae)

Members of this family are shrubs or small trees Only one genus, the ceanothi or soapblooms (*Ceanothus*), contributes abundantly to the browse crop Although the buckthorns (*Rhamnus* spp) of this family are cropped to some extent, they are not important enough to justify discussion of them here

Ceanothi or Soapblooms (*Ceanothus* spp)

Several species of ceanothi are browsed in varying degrees, but deerbrush (*C integerrimus*) is by far the most important Deerbrush, also called mountain lilac and sweetbrush, is a loose, slender, branched shrub 6–12 feet tall, with large, delicate, entire, deciduous leaves and panicles of pale blue or white flowers (Fig 51*A*) It occurs commonly on moderately dry, fertile soils in the coniferous belt on the west slopes of the Cascades of Oregon and the Sierra of California Everywhere it is cropped avidly by livestock and game animals in spring and summer but only lightly in the autumn when nutritive values decline sharply Since deerbrush stands are often dense, their grazing capacity is high Its over-all forage rating is "excellent "

Other Ceanothi

Several other species of ceanothi having some browse value are wedgeleaf ceanothus (*C cuneatus*) and whitebark soapbloom (*C leucodermis*), both common constituents of the chaparral association of California, and snowbrush (*C velutinus*) and red soapbloom (*C sanguineus*), which occur most abundantly in British Columbia, northern California, Idaho, and Montana These species are moderately palatable to livestock and are important game animal food

Willow Family (Salicaceae)

Members of the willow family are included in two genera willows and poplars

Willows (*Salix* spp)

The willows constitute a genus of some 250 species of trees and shrubs a group familiar to most persons They commonly occupy stream banks and flats or slopes bordering on wet sites over much of the North American continent, ranging from sea level to timberline

Willows produce an enormous volume of browse on the western mountain range Their palatability varies according to species and associated plants but they are cropped most in the autumn (4) Sheep

Oregon and Washington The elevational range is from sea level to 9000 feet where it occupies well-drained but moderately moist soils In many localities the palatability is high when the leafage is lush and is moderate when the leafage has matured All livestock, as well as deer and elk, feed upon this plant Its over-all browse value is good

CHOKECHERRIES (*Prunus* spp)

These are shrubs or small trees with simple, serrate leaves and clusters of white flowers Two species black chokecherry (*P melanocarpa*) and western chokecherry (*P demissa*), are widely distributed and rather common on the western range They occur from near sea level at their northern limits to about 9000 feet in the Rocky Mountains, commonly occupying sunny, moist, or rather dry sites in association with willows, aspen and ponderosa pine Although poisonous under some conditions the chokecherries are moderately palatable to sheep and goats but are little cropped by cattle Deer and elk often browse them closely, apparently with impunity On overgrazed range, poisoning of sheep by these plants is sometimes severe, since a lethal dose of the toxic substance, prussic acid acts quickly (Chapter 21) The over-all range value of these plants is "poor"

CHAMISE (*Adenostoma fasciculatum*)

This evergreen, rather spreading shrub, also called greasewood, has heathlike, somewhat resinous foliage and a spreading growth habit, developing from 2–10 feet high (Fig *50F*) It occurs most commonly in the coastal range of California south to Lower California, from near sea level to about 5000 feet It is the most characteristic shrub of the California chaparral After a fire numerous vigorous sprouts and seedlings are produced which perpetuate the stand (*22*)

The browse value of chamise ranges from nearly worthless to fair, or even good under some circumstances Old stands are often so dense as to exclude stock and little of the current growth of adult bushes is within reach of stock On the other hand, the young succulent crown sprouts of the first year's growth after a fire are grazed with relish by livestock and game especially sheep and deer The third year after a fire the sprouts become too fibrous to be edible Chemical study has shown that the first year's sprouts up to early summer are moderately high in crude protein and in calcium and phosphorus (*17*, *22*) As a whole, chamise is of low browse value despite its local abundance, its general rating being fair to "poor"

and goats are especially fond of them, but cattle utilize them most completely because of the greater reach of these animals and the fact that they readily venture onto moist or wet places where willows grow. The general food value of this group is "good."

Aspen (*Populus tremuloides*)

Aspen, also called quaking aspen, is the only species of the genus *Populus* of wide browse value. It occurs from Labrador and Hudson Bay to Alaska through southern Canada and the United States (except the South Atlantic and Gulf states) and in northern Mexico. Its elevational range is from sea level in the far north to 11,000 feet in the Rocky Mountains. Since aspen inhabits moist and rather fertile soils, a luxuriant undergrowth of various shrubs and herbs is characteristic.

Cattle are moderately fond of the leaves and twigs of aspen. Sheep, goats, deer, and elk especially relish them and, on heavily grazed areas, may crop so closely that they prevent establishment of aspen reproduction. Even the fallen leaves of the autumn are eaten to some extent. In some localities it is common practice to clear cut aspen stands. Where this is done, aspen produces large numbers of root sprouts, and since the sprouts are highly palatable, such logged off areas must be protected from excessive sheep and goat browsing for the first 3 years after logging (*20*). The over-all browse rating of aspen is "good."

Honeysuckle Family (Caprifoliaceae)

Members of the honeysuckle family are erect or twining shrubs or small trees. The groups of greatest browse value are the elderberries and snowberries.

Elderberries (*Sambucus* spp.)

Elderberries are shrubs or trees with numerous pithy branches and clusters of berrylike fruits. They are typical of moist sites over a wide elevational range. Blue elderberry (*S. caerulea*) is a representative species (Fig. *51B*).

Blue elderberry grows 6–12 feet high and inhabits the foothills and montane zones from southern British Columbia and Alberta to California and Arizona, from sea level to 5500 feet in elevation. Usually the leafage is merely nibbled or left untouched in the spring but it is taken moderately well by sheep and goats and lightly by cattle in the summer. In the fall, after the foliage has been killed by frost, all stock feed eagerly upon it, sheep preferring this darkened but still succulent growth to that of any other feed at that season. Deer and elk are also fond of the foliage and tender twigs in the autumn

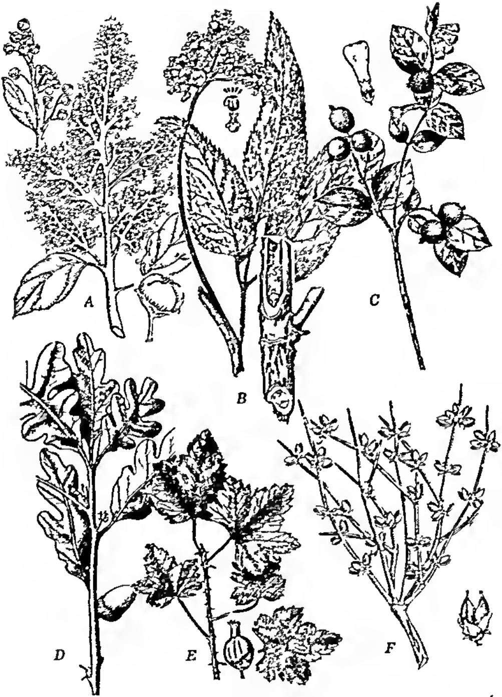

FIG. 51 *A* Deerbrush (*Ceanothus integerrimus*) *B* blue elderberry (*Sambucus caerulea*), C, mountain snowberry (*Symphoricarpos oreophilus*) *D* Gambel oak (*Quercus gambelii*) *E* whitestem gooseberry (*Grossularia inermis*) *F*, Nevada jointfir (*Ephedra nevadensis*)

Gambel oak is a shrub or small tree ranging from Arizona, Utah, and Wyoming southward to western Texas and into Mexico, where it occupies intermediate elevations (Fig. 51*D*). It sometimes forms pure stands but is more commonly associated with various shrubs in woodlands and ponderosa pine forests. Its abundant leafage is moderately palatable to cattle, sheep, and goats and to deer and elk, notably in spring and early summer where there are few other highly preferred plants. Forsling and Storm (7) concluded that close use of Gambel oak indicates overgrazing of the more palatable shrubs and grasses. Marsh, Clawson, and Marsh (*14*) noted that cattle become constipated and may develop fatal sickness when forced to subsist upon an almost exclusive diet of Gambel oak. There is almost no danger of oak poisoning, however, where the range is properly managed.

Other Oaks

Among other oaks that are browsed in varying degrees are Arizona white oak (*Q. arizonica*), California black oak (*Q. kelloggii*), California scrub oak (*Q. garryana*), Brewer oak (*Q. breweri*), shrub live oak (*Q. turbinella*), and interior live oak (*Q. wislizenii*).

In view of the large volume of browse produced by the oaks, their over-all rating is on the lower scale of "good."

Gooseberry and Currant Family (Grossulariaceae)

This is a small family of shrubs of 2 genera: gooseberries and currants. They are multibranched plants, often with spiny stems which are clothed with numerous small leaves, and they have edible berries. This family is sometimes included in the saxifrage family.

Gooseberries (*Grossularia* spp.)

Not less than 23 species of gooseberries (sometimes merged in the genus *Ribes*) are native to the western states. The less spiny-stemmed species are browsed more closely than the prominently thorny forms. Whitestem gooseberry (*G. inerme*), an almost spineless plant, which grows 1–6 feet tall, is one of the better species. It occurs throughout the Rocky Mountains and the Northwest between elevations of 2000 to 9500 feet (Fig. 51*E*). Although cropped little where other superior browse prevails, sheep, goats, and game animals feed upon the leafage to a considerable extent, and cattle take it moderately. Considering the abundance, wide distribution, and accessibility of whitestem gooseberry, and of the group as a whole, the over-all food value rating is "fair."

Despite the seasonal preference for this and most other species of elderberries they are not particularly important, because the stands are seldom extensive or dense and a large proportion of the branches grow beyond the reach of the animals Accordingly, their general range value is rated as fair

SNOWBERRIES (*Symphoricarpos* spp)

This widely distributed genus has only 12 species They are low, many-branched shrubs and are best recognized by the white berries containing the seeds They occur commonly at intermediate elevations in the Rocky Mountains and on the Pacific Coast, usually in woodland or open forest Mountain snowberry (*S oreophilus*) is among the most conspicuous shrubs in the aspen-fir belt of the Intermountain region and is fairly representative of the other species (Fig 51C)

The palatability of mountain snowberry varies from poor to good for sheep and goats, and fair for cattle, deer, and elk It is not cropped by horses This and other snowberries withstand grazing well, and in many localities contribute moderately to the range food supply Their general forage rating is "fair"

Oak or Beech Family (Fagaceae)

Members of the oak family are well known as trees and shrubs, with deciduous or nondeciduous leaves and fruit a characteristic acorn The oaks (*Quercus* spp) constitute by far the most important group of the oak family on the range Stock seems to prefer those with deciduous leaves over the live oaks that have nondeciduous leaves Mackie (*13*) reported that the nutritive value of oak leaves is relatively well balanced, except that they are quite high in crude fiber, resins and waxes, and tannin Gordon and Sampson (*8*) noted that the ratio of calcium to phosphorus in young leaves of blue oak (*Q douglasii*) was nutritionally satisfactory, being 2 2 1, but that it was disproportionate at leaf maturity, the ratio then being about 15 1 They also reported that the acorns of this species are distinctly low in crude protein and high in crude fiber and in fats and oils These facts account for the good fattening qualities, but poor growth and bone building balance, of the acorn mast which is utilized so extensively by hogs, deer, and some other animals in the autumn

GAMBEL OAK (*Quercus gambelii*)

Although the oaks vary widely in the extent to which they are cropped by stock and game animals, Gambel oak is selected here to indicate, in a broad way, the browse value of deciduous species

drons (*Rhododendron* spp.), larkspurs (*Delphinium* spp.), and the like, were not mentioned, since they are discussed under the heading of poisonous plants (Chapter 21).

Such native emergency food as soaptree yucca (*Yucca elata*) and cacti (*Opuntia* spp.) were not discussed, since they too are considered elsewhere (Chapter 14).

Despite the reasons stated for not including many plants of some range food value, the author regrets the discussion could not be more complete. Even so, stockmen and range scholars should profit by learning first what the *principal* forb and browse plants of the range are, as pointed out here, and then broaden their knowledge of this subject as conditions and interest warrant.

The leading native palatable forbs and shrubs of the natural pasture areas of the southeastern states are mentioned in Chapter 15 in connection with management practices in that region.

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Currants (*Ribes* spp.)

There are some 56 native currants in the western states. They are mostly unarmed (spineless) shrubs and are common plants of the foothills and mountains. As a group the currants are perhaps somewhat less palatable than the gooseberries. They are cropped most closely by goats but sheep and big game animals feed upon them to a considerable degree. Since currants are the alternate host of the organism causing the white pine blister rust, they are being destroyed in stands of true pine. Cattle browse limitedly upon them in the autumn. Their over-all range food value is "fair."

Jointfir Family (Gnetaceae)

These are woody plants of the gymnospermous group and are represented on the western range by the jointfir genus (*Ephedra*), which embraces some 5 species. Being drought-enduring plants, they are most common in the semiarid regions, notably in the Southwest. Nevada jointfir (*E. nevadensis*) is typical of the group (Fig. 51F).

Nevada jointfir is a low, almost leafless shrub with numerous blue-green semisucculent stems and greenish yellow flowers. The range is from Utah to California and southward into Mexico.

Nevada jointfir, like many of the other jointfir species, is often browsed rather heavily in late fall and winter by cattle, sheep and goats and is also utilized by deer. Sometimes as much as 40 percent of the season's growth is taken (2). It is an important emergency winter feed in years of poor forage growth, the animals apparently doing well on it. Little of the growth is taken during summer months. The jointfirs generally are rated as "good."

Other Western Range Forb and Browse Plants

The preceding discussion has shown that the forb and browse plants of the western range are exceedingly numerous and greatly varied in their distribution, growth requirements, and food value.

Not included in the discussion were many so-called secondary plant groups. Collectively these groups contribute a considerable amount of feed, and a few are of much local importance (4, 21). For instance, the plantains (*Plantago* spp.) were not mentioned, yet desert Indian wheat (*P. fastigiata*) is fairly palatable and is sometimes so abundant on ranges in the Southwest as to provide much spring forage. Likewise, various "desert" plants like Brown's peony (*Paeonia brownii*), a highly palatable but seldom abundant species, were not considered. Plants that are poisonous if eaten excessively, such as the rhododen

Chapter 11

ARTIFICIAL RESEEDING, AND THE ESTABLISHMENT OF IRRIGATED PASTURES

When the white man first placed his animals on the western range, superior forage was abundant After decades of excessive grazing, weedy or denuded areas appeared, resulting in floods, soil erosion, dust storms, and bankruptcy of the operator In the absence of historic record, few realized how long, difficult, and expensive would be the task of reseeding the depleted areas by either natural or artificial means

Revegetation by natural means is usually impractical where the forage cover has been largely destroyed Under such circumstances artificial reseeding, although expensive and subject to failure, is the only recourse

Artificial Reseeding of Western Range Province

Artificial range reseeding is the reestablishment on depleted lands of a well-adapted forage cover by planting or sowing of seed or by transplanting seedlings or vegetal segments The seed of domesticated plants is most commonly used but seed or segments of native plants are occasionally employed The primary objectives are to increase the grazing capacity and control soil erosion (*3*)

About 1890 the Federal government, and later various western state experiment stations (*6*, *28*, *57*), initiated reseeding trials Much of the early work was done, though with little success, by Griffiths (*19*) and Thornber (*52*) on semidesert ranges in the Southwest In 1908 Cotton (*11*) recommended reseeding with orchard grass,[1] smooth brome, redtop, and timothy in the mountains of the Northwest Cotton's studies induced the U S Forest Service to set up more than 500 reseeding trials on national forests in 11 western states, with minimum cultural treatment Sampson (*43*) reported that 16 percent of these tests were

[1] Scientific names of plant species mentioned for use in reseeding are listed at the end of the chapter

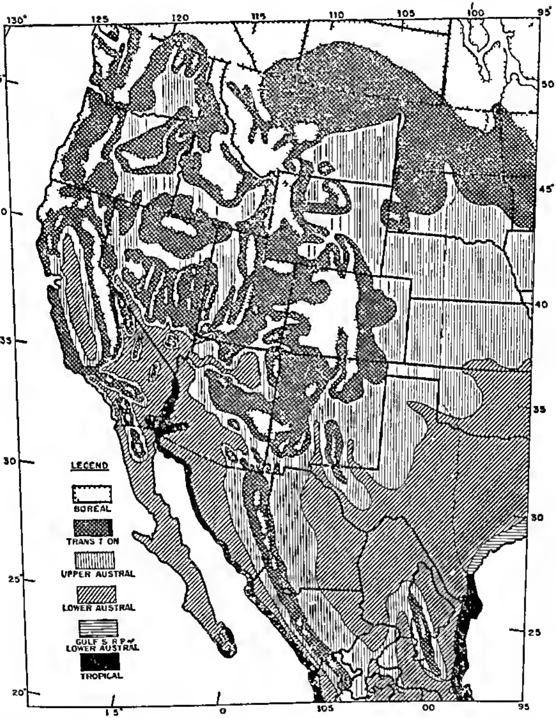

FIG. 52. Distribution of life zones in Western United States and adjacent territory. The Boreal region shown here includes the Arctic-Alpine, Hudsonian, and Canadian life zones, since these belts have not been delimited in some areas. Likewise, the zones comprising the Tropical region are not designated here. The Gulf Strip of the Lower Sonoran life zone is the only frost-free belt with the exception of the limited true Tropical region. Artificial reseeding is most successful when the species selected are properly coordinated with the life zone in which they are planted.

successful, 25 percent partially successful, 37 percent failures, and the remainder undeterminable when the experiment was discontinued

Considerations Preliminary to Reseeding

In the more recent studies special consideration has been given to site quality, seedbed preparation, seed coverage and related factors

Suitability of Site The better sites should be seeded first Good sites have a fairly deep soil of desirable texture, structure, and color, a satisfactory slope gradient and exposure, and good stature of the remaining vegetation If the soil is twice as deep on one part of the area as on another, its productive capacity for deep rooted grasses might be doubled Where 10 to 15 percent of the native choice forage stand still remains, the area may be revegetated most cheaply by natural reseeding (Chapter 12)

The primary handicap in reseeding, except perhaps in the high mountains, is insufficient moisture Success on exposed, wind swept south and west slopes is less certain than on those protected by a ridge or by a fringe of tall vegetation In all localities, elevation—which is indicated by the life zone of the area—must be compatible to the species selected

Life Zones and Their Recognition Many introduced range plants failed because they were reseeded in areas incompatible with the new life zone Plants have genetically fixed tolerance ranges to the factors of the environment A species can become established only under conditions similar to those under which it evolved

Merriam (32) was among the first American workers to map plant and animal distribution on a zonal (climatic and biotic) basis (Fig 52) Certain common native zonal plants and animals are presented in Table 2 Although Merriam's concepts of life zones have been challenged, his classification is useful to field ecologists

Recognition of the life zones is broadly useful in artificial range reseeding, because they indicate such vital factors as length of the growing season, precipitation relations, and the character of competing vegetation

Selection of Species and Seeding Rates It is safest to select those species that have locally yielded the largest continuous volume of good forage Strongly advertised but little tested species should be avoided Locally grown seed usually is most satisfactory Seeds of native species should be collected near the site to be sown, with either a hand or power-driven stripper (47)

Seed mixtures, because of diversity in root distribution, can more fully utilize the available moisture and soil nutrients than single species Also, the season's forage yield is likely to be larger, and, since all species

do not mature at the same time, the period of succulence and desirable nutrition is lengthened. Mixed seeding is especially recommended where desirable species are slow in gaining a foothold.

Many plant species, both introduced and native, have been used to improve and stabilize the soil (*17*, *22*). Sodforming grasses protect the soil best, but a good stand of bunchgrass is effective on conservatively grazed range lands.

Too dense a seedling stand wastes seed and lessens the chances of procuring a strong cover. Correct seeding rate is determined by the thoroughness of planting, the size of the seed, its purity, and its germination capacity. The buyer should be on guard for these qualities.

Season and Depth of Planting. In mountainous regions the best time to plant is in fall, shortly before the coming of winter snows. However, spring or summer planting is advisable where precipitation is adequate to keep the soil moist and where winter killing, as from soil heaving, occurs. Drilling in the seed provides the best coverage. On slopes the drilling should be on the contour to control excessive runoff.

The depth of planting is important. Small seeds, because of limited reserve food, should not be planted deeper than ½ inch; large seeds seldom deeper than about 1 inch. On light soils, and on fresh forest or brush burns where the soil has been fluffed up by the heat, a fair proportion of broadcast-sown seeds usually finds its way into the soil.

Airplane seeding appears to be practicable on large areas of cleanly burned-over land (*33*) but is often wasteful on logged-off areas and has no place on meadows, where the seed should be drilled in. On calm days airplane seeding is relatively inexpensive and rapid, generally resulting in fairly even seed distribution. The costs of the three main distribution methods were estimated for a normal peacetime year by Pickford and Jackson (*38*). Exclusive of the seed price the cost per acre was: drilling $1.00, mechanical broadcasting 50 cents, airplane seeding 25 cents.

Scattering pelletized seed by airplane or by hand has been attempted experimentally, mainly in the Southwest, Idaho, and Montana. Credited to Dr. L. S. Adams, retired dentist (*55*), the pelletized seeds are mechanically compressed into quarter-inch size from prefertilized clay soils. Pelletizing is meant to give the seedlings a vigorous start and to protect the seeds from birds or rodents. But pelletizing has not been successful, largely because the seed-carrying pellets are generally left on the surface of the ground; manufacturing and scattering of the added bulk is expensive; and it has sometimes resulted in appreciably reducing seed viability. Drilling in the seed at proper depth may be expected to give results far superior to broadcasting of either

Fertilization of range or meadow soils tends to increase nutrition and palatability of the forage or hay. The animals tend to graze the forage closely on areas where a *needed* fertilizer has been applied, whereas they crop unfertilized units supporting the same kinds of plants only moderately or lightly. Perhaps, by selecting small areas for fertilization much as one would choose places for salting, better distribution of livestock over the range may be obtained. If this should prove effective, slightly different sites should be fertilized each year to avoid overutilization of such areas. Similarly, livestock, if given a choice, also prefer hay from the fertilized portion of a meadow. Often the hay from the fertilized soil is more or less completely eaten before any appreciable amount of the unfertilized portion is taken. Albrecht, (*1*), speculating on food selectivity, states:

TABLE 3

APPLICATION OF COMMERCIAL FERTILIZERS

Element	*Carrier*	*Rate per Acre*
Calcium	Ground limestone	1 ton
Phosphorus	Superphosphate	300–500 lb
Potassium	Muriate or sulfate of potassium	100 lb
Nitrogen	Nitrate of soda	100–200 lb
	or	
	Sulfate of ammonia	75–150 lb
	or	
	Barnyard manure	5–10 tons
Sulfur	Gypsum	400 lb
	or	
	Soil sulfur	80 lb

> Just what particular chemical compound in the food helps the animal to discriminate and whether it does so by smell as well as by taste are still open questions. . . . That the animal's delicacy in selecting food serves for its better body growth is clearly suggested in work to date.

On portions of the coastal annual foothill ranges of California, cattle are attracted to areas fertilized with 300 pounds per acre of ammonium phosphate (16–20–0), but, in parts of the drier San Joaquin country, cattle closely graze areas fertilized with 300 pounds per acre of gypsum or soil sulfur. Forage production has increased appreciably in normal rainfall years where needed fertilizers were applied, but little or not at all in abnormally dry seasons.

Soil Analysis. Chemical analysis of range soils seldom furnishes the operator with a direct answer to reseeding possibilities, largely because

pelletized or free seed in obtaining an initial stand Where birds are likely to consume much of the naked broadcast seed, the seed may be treated with the dye National Brilliant Yellow, S P The county agent should be consulted for specific directions

Seedbed Preparation and Seed Coverage On productive sites it usually pays to prepare a good seedbed The ideal seedbed for grasses and legumes consists of a fairly loose and fine-textured topsoil over a firm and moderately deep subsoil On compact, weed-covered soils, disking and then seeding with a grain drill is usually satisfactory On loose, sparsely vegetated sites, a spike-tooth harrow accomplishes the same end In open deciduous forest, such as aspen or oak, seeding in the autumn before leaf fall usually provides adequate seed coverage Plowing, except of the highest quality sites, is usually too expensive (*36, 45, 49*) On gentle slopes where the soil is compact, plowed furrows spaced several feet apart provide a good seedbed at low cost

Use of Fertilizers Most forage crops yield more heavily when suitably fertilized In humid, eastern United States, pasture soils are commonly deficient in calcium, phosphorus, and nitrogen, and some in potassium (*41*) In the arid West, deficiencies in phosphorus and nitrogen are common (*15, 54*) In some areas success is achieved by applying annually a top dressing of nitrogen, such as sodium nitrate, to favor the grasses, or of nitrogen and phosphorus, such as ammonium phosphate (16–20–0), to stimulate growth of legumes and grasses, or of gypsum to supply needed sulfur, or, less commonly, of potash

Both commercial fertilizers and barnyard manures are effective on pastures Commercial fertilizers usually supply nitrogen, phosphorus, and potassium, singly or in a combination called a *complete* fertilizer The percentage of nitrogen, available phosphoric acid, and water-soluble potash is expressed in a combination of numbers, such as 4–16–4, implying a proportion of 4 percent nitrogen, 16 percent phosphoric acid, and 4 percent potash

Commercial fertilizers—used either singly or in combination as shown in Table 3—and barnyard manure, can be expected to increase the yield of many pastures that have a fair stand of desirable forage plants. Top dressings of the commercial fertilizers should preferably be applied 1 to 2 weeks after spring growth starts, or they may be disked in, using a fertilizer spreader, just before reseeding

Barnyard manure is a natural and the best all-around fertilizer Application at 3-year intervals is satisfactory A great waste of pasture fertility results from having shade trees and stock watering tanks on the lower rather than on the higher portion of the pasture where fertilizer effects would be better distributed

chiefly on the national forests (Fig. 53, I*d*), present a problem distinct from that of the Coastal region.

South Coastal Division. The southern division (Fig. 53*A*) includes all of California except the southeastern desert and the mountain strip along the eastern border. Jones and Love (27) divided this area into three units: southern, central, and northern.

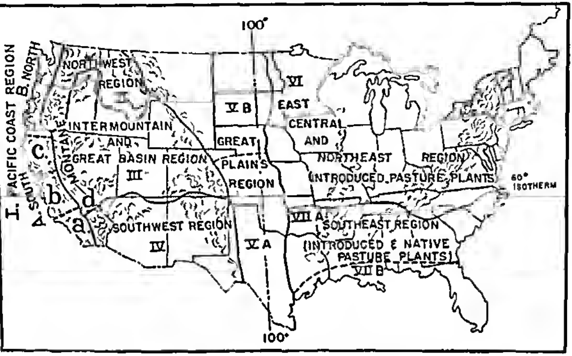

FIG. 53. Major pasture regions of the United States. Each region requires selection of adapted species for successful artificial reseeding.

The southern unit (Fig. 53, I*a*) of the California Coastal division, with its dry, hot summers and competing annual vegetation, is the most difficult to reseed. Mowing or spraying this cover with 2,4-D or one of its derivatives once or twice early in the summer is helpful. Judicious selection of species for reseeding is especially important (*4*). Along the coast the following have given best results: birdsfoot trefoil, burclover, burnet, Dallis grass, foothill needlegrass, Harding grass, Ladak alfalfa, orchard grass, Rhodesgrass, ryegrasses, subterranean clover, or mixtures of these. In the drier interior sites of the southerly unit only the most drought-enduring species, including native perennials, have shown any promise.

In the central coastal unit (Fig. 53, I*b*) essentially the same species are useful, but on the drier inland sites a combination of perennial ryegrass, the needlegrasses, and California brome may be established. These are best planted with a press drill in the stubble of plowed fields shortly before the beginning of the rainy season.

the soil types are numerous even in local areas and the relationships between soils and plant life are highly complex. Soil analysis, however, may be helpful to the range investigator who is studying such problems as fixation of nutrients, distribution of fertilizers in soils, and problems of alkalinity and salinity.

Chemical soil analysis determines the amount of readily available nitrogen, phosphorus, potassium and, perhaps, of certain trace elements. The kind of combination of commercial fertilizers needed will depend on the vegetation to be grown. Grasses generally respond best to top dressings of nitrogen or nitrogen and phosphorus, legumes to applications of calcium, phosphorus, and/or sulfur.

If chemical soil studies are undertaken as a part of reseeding experiments they should be initiated at the outset in order to determine the nutrient levels of the main soil types. The species to be seeded may first be grown in pot cultures in a greenhouse where the effects of various fertilizers may be observed in a preliminary way.

Broadly considered, then, soil analysis may be useful in range research but is of doubtful value to the individual land owner. The investigator should never lose sight of the fact that there is no substitute for close observation of plant response on adequate numbers of properly located field test plots.

Management of Newly Planted Areas

Most reseeding efforts will come to naught if the seedling stand or planted segments are grazed before they become well established. In the West, most newly planted areas should have no less than 1—or possibly 2—years of total protection from livestock grazing, preferably by fencing. Rodents should be poisoned where numerous, and heavy infestation of weeds should be mowed in early summer.

Regional Considerations in Reseeding of Western Range

In selecting plants for seeding in different geographical areas, the writer has followed a previously used plan (*48*) of dividing the nation's pasture lands into seven broad climatic regions (Fig. 53).

I. **Pacific Coast Region.** A large part of the Pacific Coast region lies mostly in the Sonoran and Humid Transition life zones along the ocean from southern California to northern Washington including the valleys and foothills (Fig. 53, I). The climate is mild—the summers dry and hot, the winters rainy. Since the California portion receives less precipitation than the coastal region northward and has a distinctive flora, the Pacific Coast region is divided into a South Coastal division and a North Coastal division. In addition, the mountain lands, located

associates (*48*) recommended special seed mixtures for different ecological sites,[2] as shown in Table 6.

In the entire Pacific Coast region the following species are used in erosion control and for soil building

Alfalfa	Orchard grass
Australian saltbush (I*A*, *a*)	Perennial ryegrass (I*A*, *a*, *b*)
Beardless wild rye	Purple needlegrass
Birdsfoot trefoil	Redtop
Blue wild rye	Smilo (I*A*, *a*)
Bur-clover (I*A*, *a*)	Subterranean clover
California brome (I*A*, *b*, *c*)	Sudan grass
Filaree (I*A*, *a*)	Tall fescue
Harding grass (I*A*, *b*, *c*)	White clover
Italian ryegrass (I*b*, *c*)	Wimmera ryegrass (I*A*, *a*)
Junegrass	Yellow sweetclover
Kikuyu (I*A*, *a*)	

TABLE 4

SUITABILITY OF SPECIES FOR SEEDING DIFFERENT VEGETAL AREAS IN THE CALIFORNIA MOUNTAIN REGION*

Species	*Great Basin Sagebrush (Transition Zone)* 4000–5000 ft		*Ponderosa Pine (Transition Zone)* 5000–7500 ft		*Red Fir—Lodgepole (Canadian Zone)* 6000–9000 ft	
	Dry Sites	Moist Sites	Dry Sites	Moist Sites	Dry Sites	Moist Sites
Crested wheatgrass	x		x			
Smooth brome		x		x		
Timothy		x		x		x
Intermediate wheatgrass	x	x	x	x		
Pubescent wheatgrass	x	x	x	x		
Redtop				x		x
Mountain brome					x	
Reed canary		x		x		x
Big bluegrass	x		x			
Slender wheatgrass			x	x	x	x
Blue wild rye			x		x	x
Tall meadow oatgrass				x		x
Orchard grass				x		x

* Unpublished data used through permission of the *Calif Forest and Range Expt Sta*, Berkeley, Calif Seeding guides for the North Coast division are presented in Table 5

[2] The author has supplemented Semple's lists by adding tall fescue and subterranean clover, because of their favorable responses in more recent experiments.

In the northern unit (Fig. 53, 1c) the species recommended are birdsfoot trefoil, burnet, California oatgrass, Harding grass, hop clover, needlegrass, orchard grass, ryegrasses, tall fescue, and tall meadow oatgrass. Here grasses do better than legumes.

On selected sites near the San Francisco Bay, the Soil Conservation Service has succeeded in establishing experimentally, such species as Harding grass, needlegrasses, burnet, California oatgrass, perennial ryegrass and some legumes. To what extent these stands can be maintained under grazing is problematical.

Converting brushfields to a grass cover is another reseeding problem in parts of the South Coastal region. The brush is burned in summer and seeded in fall. Love and Jones (*50*) have proposed various mixtures of perennial grasses and legumes. But reseeding of these areas to perennials is hazardous and still in the experimental stage.

Because of the severe competition of chaparral sprouts and seedlings and of herbaceous vegetation, the author favors—if any reseeding is to be undertaken—the use of annual species such as cereal rye, Italian ryegrass, wild oat, soft chess, and rose clover. These plants become established much more quickly than perennials, provide some forage, protect the otherwise exposed soil from severe erosion, and tend to suppress invading brush seedlings. However, burns on which perennial grasses occur in some abundance may be seeded to such perennials as Harding grass, smilo, and tall meadow oatgrass (Chapter 13).

California Mountain Lands. These lands (Fig. 53, 1*d*) lie between elevations of some 4000 to 9000 feet. A large part of the grassland needs reseeding, particularly the meadows.

In the northern portion of this unit the U. S. Forest Service, the Soil Conservation Service, and the Extension Service of the University of California have concluded that crested wheatgrass and smooth brome give the best general results (Table 4). Other species listed in the table have shown promise in various habitats. But the studies are still in the experimental stage.

North Coastal Division. The relatively favorable growth conditions in this division—Transition and more elevated life zones (Fig. 53*B*)—have induced a fairly extensive reseeding program. Competition with native species is partly overcome by seeding with aggressive species and by mowing or using selective sprays. In parts of this region a rather large acreage of nonrestocking cutover and burned timberland has been converted to pasture. Daniel and Ensminger (*13*) reported best results from fall seeding, and they recommended the seed mixtures shown in Table 5.

Working with other than cutover lands of this region, Semple and

II. Northwestern Region. The Northwestern pasture region lies inland in Oregon and Washington and in the northern half of Idaho (Fig 53, II) It consists largely of open stands of coniferous forests or of cutover or burned timber lands in the Boreal region, and in the

TABLE 6

SEEDING RECOMMENDED FOR NONCUTOVER LAND, NORTH COASTAL DIVISION

For Moist Bottom Lands	Pounds per Acre	For Fertile Uplands	Pounds per Acre
Tall fescue	4	Tall fescue	4
Italian ryegrass	3	Italian ryegrass	4
Perennial ryegrass	3	Tall meadow oatgrass	4
Kentucky bluegrass	4	Orchard grass	4
Subterranean clover	2	Kentucky bluegrass	4
White clover	2	Subterranean clover	3
Red clover	2	White clover	2
or		Red clover	2
Alsike clover	2	or	
Total	20	Alsike clover	2
		Total	27

For Land Subject to Flooding

Short Periods	Pounds per Acre	Long Periods	Pounds per Acre
Seaside bent	5	Reed canary	8–12
Meadow foxtail	5	or	
Italian ryegrass	4	Seaside bent	8–10
Alsike clover	4		
Total	18		

For erosion control and soil building in this region the following species are among the most useful

Beardless wild rye	Kentucky bluegrass
Bluestem wheatgrass	Redtop
Blue wild rye	Slender wheatgrass
Canada bluegrass	Smooth brome
Crested wheatgrass	Thickspike wheatgrass

III Great Basin and Intermountain Region The great diversity of elevation, climate, and soils of this vast region (Fig 53, III), embracing the Boreal region, and the Arid Transition and Upper Sonoran life zones, has stimulated trials with many forage species Best results may be expected in the cooler, heavier-rainfall mountain and foothill zones and the poorest in the drier and hotter Sonoran semidesert zone

Best seeding time is generally in September and October, before the coming of snows, but, in the mountains where summer rains are abundant, seeding in July and August is satisfactory (*50*, *51*)

On mountain ranges of medium elevation in eastern Oregon, a border area of the Intermountain region, Pickford and Jackman (*38*) recommend the mixed seeding in the various life zones and sites as shown in Table 7

For seeding near timber line—Hudsonian zone—where the annual precipitation averages some 30 inches and the growing season is 75 to 90 days, Forsling and Dayton (*17*) recommend the species shown in Table 8, planted singly

Most of these species are also employed in the mountain and foothill ranges of Colorado, Nevada, Utah, and western Wyoming On some sites in these states bulbous bluegrass, Canada bluegrass, the ryegrasses, and several native wheatgrasses are used

On cleared sagebrush and scrub oak cover (Arid Transition zone) in Utah, Price (*40*) and Stoddart (*51*) obtained some good stands with crested wheatgrass, smooth brome, bearded wheatgrass, and big bluegrass Stewart, Walker, and Price (*50*) reported good results with a combination of bluebunch wheatgrass, western wheatgrass, crested wheatgrass, and smooth brome, and on some sage brush sites, alfalfa, intermediate wheatgrass, stiffhair wheatgrass, slender wheatgrass, and tall fescue were successful On rockless areas the wheatland plow (one-way disk) or an offset disk were best for removing the sagebrush, on rocky areas the Dixie harrow was effective

For well-drained mountain meadows, Stewart, Walker, and Price (*50*) recommend Kentucky bluegrass, orchard grass slender wheatgrass, and timothy

the fire. They recommended a mixture of 3 to 5 pounds of a suitable combination of the following species timothy, orchard grass, Kentucky bluegrass, tall fescue, meadow fescue, Chewings fescue, highland bentgrass, smooth brome, and slender wheatgrass. Better stands were obtained on the lighter than on the heavier burns

The following species are recommended for the lower and drier mountain slopes and higher foothills bulbous bluegrass, timothy, and such native grasses as Canada wild-rye, greenleaf fescue, and Sandberg bluegrass

Near timber line (Hudsonian life zone), on inland mountains generally, Forsling and Dayton (*17*) recommended seeding with these species Canada bluegrass, Kentucky bluegrass, smooth brome, redtop, and thickspike wheatgrass (these five are sodformers and may be maintained where the growing season is too short for seed formation), slender wheatgrass and big mountain brome.

For general use on inland mountain ranges Forsling and Dayton recommended the following plants, these being considered suitable for seeding both in the Northwest region and eastward from the west coastal slope.

the advent of the characteristic summer rains The combined effects of protracted droughts strong winds, and overgrazing have replaced much palatable forage with burroweed, cactus, cholla, juniper, and mesquite These lands can best be improved by conservative cropping and deferred grazing to favor natural reseeding where ample seed plants remain But, where natural revegetation is too slow, artificial reseeding trials with adapted species are justified

Especially recommended sites (7, *35*, *42*) for seeding are (1) denuded range where soil and moisture conditions are above average, such as flats and meadows that are naturally flooded, (2) denuded

TABLE 8

SEEDING RECOMMENDED NEAR TIMBER LINE, GREAT BASIN AND INTERMOUNTAIN REGION

Seed Available on Market Cultivated Species	*Pounds per Acre*	Seed Not Available on Market, Native Species	*Pounds per Acre*
Smooth brome	15	Slender wheatgrass	15
Kentucky bluegrass	15	Big mountain brome	20
Canada bluegrass	15	Thickspike wheatgrass	15
Redtop	8		

and eroding hilly lands where a denser plant stand can be induced by contour furrowing and other such techniques, (3) abandoned farm land and steep slopes that will support a permanent pasture cover, (4) dikes, banks, dams, spillways, denuded areas along highways, and similar sites

Special techniques for planting the seed and protecting the seedlings are helpful On light soils the seed should be scattered broadcast and covered by dragging a brush harrow or other light implement over the area, or by trampling of sheep After that, the area should be mulched with straw

On the heavier soils the seed should be drilled in, a cultipacker (Fig 54) being useful On especially critical areas, transplanting of vigorous segments of nursery-grown stock or of plants dug up from the natural stand is an expensive but good method of establishing native perennials (*35*, *44*)

All reseeded or transplanted areas must be protected from livestock grazing for 2 full growing seasons Jack rabbit and rodent control, especially on mesquite lands, must be carried out before revegetation is undertaken and repeated when needed

Species recommended for seeding are broadly divided into two

TABLE 7

SEEDING RECOMMENDED FOR MEDIUM ELEVATION RANGES, EASTERN OREGON

Sagebrush Hillsides or Dry Meadows

	Pounds per Acre
Crested wheatgrass (not used much above 5000 ft or where rainfall greatly exceeds 16 in)	2
Big bluegrass	1
Bluebunch wheatgrass	1
Tall meadow oatgrass	1
Total	5

Ponderosa Pine Logged-off Land, Low Rainfall*

	Pounds per Acre
Crested wheatgrass	2
Idaho fescue	1
Chewings fescue	1
Mountain brome	2
Total	6

Ponderosa Pine Logged-off Land, Good Rainfall

	Pounds per Acre
Orchard grass	2
Tall meadow oatgrass	2
Chewings fescue	1
Kentucky bluegrass	1
Timothy	1
White sweetclover	2
Total	9

Good Meadows with Deep Soil, Well Drained

	Pounds per Acre
Tall meadow oatgrass	2
Smooth brome	2
Tall fescue	2
Timothy	1
Ladak alfalfa	1
Total	8

Meadows Wet in Spring Period

	Pounds per Acre
Bluestem wheatgrass	4
Meadow foxtail	1
Redtop	1
Alsike clover	1
Total	7

High Elevation, Burned-Over Land

	Pounds per Acre
Timothy	2
Orchard grass	2
Chewings fescue	0 5
Tall meadow oatgrass	0 5
Meadow foxtail	0 25
Astoria bentgrass	0 25
Total	5.5

* In recent experimental trials intermediate wheatgrass and stiff hair wheatgrass have given good results on cutover ponderosa pine lands in the Blue Mountains of eastern Oregon and in Idaho

For erosion control and soil building (*18*), the following species are recommended

Astoria bentgrass	Crested wheatgrass	Smooth brome
Bluebunch wheatgrass	Kentucky bluegrass	Tall meadow oatgrass
Bluestem wheatgrass	Ladak alfalfa	White clover

IV. Southwestern Region The Southwest embraces southeastern California, Arizona, New Mexico, and western Texas (Fig 53, IV) and lies chiefly in the Arid Transition and Upper Sonoran life zones In this hot, dry region, rainfall is about 15 inches or less a year

Current reseeding studies include those by Bridges (7), Cassady and Glendening (*9*), Crider (*12*), Enlow (*16*), Parker and McGinnies (*35*), Reynolds and associates (*42*), Valentine (*53*), and Wilson (*58*) These workers recommend planting in June or early July, just before

best, but two introductions from South Africa, Lehmann lovegrass (Fig. 55) and weeping lovegrass have given promising results in the southern portion of this region (*12, 35, 42*). The earlier reputation of low palatability of these plants has been partly disproved, when green and succulent, they are moderately palatable to stock. However, their seed is not yet available on the market.

TABLE 9

SPECIES SUITABLE FOR SEEDING SEMIDESERT LOWLANDS

	Pounds per Acre (when planted singly)		*Pounds per Acre* (when planted singly)
Alfilaria	10–15*	Indian ricegrass	10–15
Alkali sacaton	2–4	Lehmann lovegrass	1–2
Big bluestem	7–12	Mesa dropseed	2–4
Black grama	8–14	Rothrock grama	5–10
Blue grama	3–5	Sand dropseed	2–4
Buffalo grass	1–2	Tanglehead	4–6
Chamiza	10–12	Tobosa	5–10
Curly mesquite	10–15	Vine-mesquite (also sod transplant)	12–15
Fourwing saltbush	15–18	Weeping lovegrass	3–4
Galleta	5–10	Winterfat	10–15
Hairy grama	3–5		

* Use the larger amount of seed on the more productive sites and where the seed is broadcast.

Species Suitable for Uplands, in open forest or sagebrush of the Arid Transition zone are listed in Table 10. Since precipitation is relatively heavy, seeding is more successful here than in the drier lowlands. The zones grazed most are the ponderosa pine and sagebrush-woodland.

Reynolds and associates (*42*), working in Arizona and New Mexico, have tentatively recommended the species and rates of seeding presented in the table.

The techniques of seedbed preparation, planting, and management of the seedling stand applies as strictly in these zones as elsewhere.

V. Great Plains Region. The Great Plains region, extending from the Canadian to the Mexican border (Fig. 52), embraces mainly the Upper Sonoran life zone, but in the northern portion the Arid Transition zone is well represented. The diverse climate necessitates use of many species or strains in reseeding.

Southern Great Plains. This division (Fig. 53, *VA*) lies in the Upper and Lower Sonoran life zones. Although this area receives more rainfall than the Southwest region, several of the same species are used in reseeding.

Here the chief task is to reseed abandoned, plowed, terraced, or

categories: those suited to the semiarid lowland grass zone, and those best adapted to the more elevated and moister forest zone.

(Soil Conservation Service)

FIG. 54. *Above,* eccentric disk with cultipacker-seeder attached behind; *below,* pits formed by eccentric disk filled with water from a light shower.

Species Suitable for Semidesert Lowlands, below 6500 feet in the Upper and Lower Sonoran life zones (*29, 53*) are listed in Table 9.

Few of the species listed above can be established where the average annual precipitation is below 12 inches. In general, native species are

low-yielding farm lands (*31, 46*). Because of possible wind erosion the seed is often drilled into a protective stubble left by a previous crop such as cane, Sudan grass, kafir, or sorgo. Small-grain stubble is seldom satisfactory for grass seeding. Only in protected sites should the land be clean-tilled (*9*). Sorghum is commonly sown the first year—adapted grasses the second year.

TABLE 10

SPECIES RECOMMENDED FOR SEEDING IN TWO UPLAND ZONES AND AMOUNT OF SEED TO BE PLANTED

Zone	*Annual Precipitation*	*Species*	*Seed per Acre When Planted Singly (pounds)**
Ponderosa pine	Above 25 in	Orchard grass	5–8
		Smooth brome	8–12
		Tall meadow oatgrass	7–10
	20–30 in.	Slender wheatgrass	8–12
		Big bluegrass	5–8
		Crested wheatgrass	5–8
		Intermediate wheatgrass	6–9
Sagebrush and woodland	Above 15 in.	Crested wheatgrass	5–8
		Bluestem wheatgrass	8–12
		Chamiza	10–15
		Sand dropseed	2–4

* Use the larger seed poundage when broadcasting, the smaller poundage when planting with drill, cultipacker, or lister. Plant in 6-inch rows where annual precipitation is above 20 inches, 12-inch rows where it is below 20 inches.

Many attempts at artificial reseeding have failed because of severe competition with weeds (*45*). In many areas natural reseeding, either through deferred grazing or by conservative forage use, appears to be the most practical means of revegetating. On suitable sites, however, artificial reseeding has resulted in increased capacity and the production of more pounds of beef than is possible on native range.

On some sites the practice of "pitting" the soil with an eccentric disk to hold moisture from rains has been helpful in establishing seeded areas (Fig. 54).

The time of seeding depends upon the method of land preparation and the forage species used. Late March to early April is best for warm-season grasses which require fairly high temperatures for growth; fall or early spring seeding is best for cold-season grasses.

The mixtures recommended by Savage and Smith (*45*) for different sites are given in Table 11.

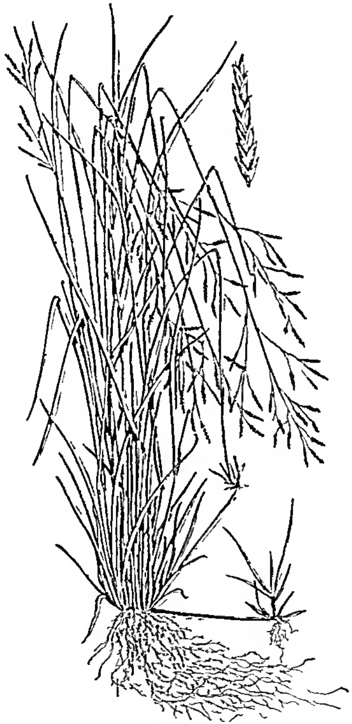

Fig. 55 Lehmann lovegrass, a useful forage and soil stabilizer for reseeding in the Southwest

come dormancy Now much more buffalo grass is planted in the Great Plains with seed than with sod pieces, usually in mixture with grama grasses

Where native bluestems occur, King-ranch bluestem, native of India, should be tried This plant has been grown successfully on test areas from the Gulf Coast to northern Oklahoma

Northern Great Plains The gently rolling plains of bunchgrasses and sagebrush in the middle and eastern portion are in sharp contrast

TABLE 12

SPECIES RECOMMENDED FOR SEEDING IN NORTHERN PLAINS REGION

Species	*Where Adapted*	*Seed per Acre* (pounds) Drilled	Broadcast
Blue grama	Plains	5 7	6–8
Bluestem wheatgrass	Plains ranges, heavy soils	6–8	8–10
Crested wheatgrass	Foothills, plains, valleys	3–5	4–6
Indian ricegrass	Mountains, valleys, sandy soils	5–7	6–8
Ladak alfalfa	Plains, foothills, swales	3–5	4–6
Mountain brome	Mountains, exposed subsoil	8–10	10–12
Orchard grass	Mountains, intermediate valleys	4–6	5 7
Smooth brome	Mountains, plains, swales	6–8	8–10
Tall meadow oatgrass	Mountains, moist sites	5–7	6–8
Timothy	Mountains, moist sites	3–4	4–6
Yellow sweetclover	Foothills, plains	3–5	4–6

to the rugged boreal forested chain of the Rocky Mountains in the western part of this region (Fig 53, *VB*) Climate, soil, and reseeding practices (*23*, *24*) are also vastly different

Areas heavily covered by undesirable vegetation, such as downy chess or tumbleweed, should be disked or harrowed before planting Short (*49*) recommended seedbed preparation in the fall when the soil was moist from rains On the steeper slopes he proposed contour furrowing at intervals of 8 to 12 feet, using a reversible hillside plow Broadcast seeding was satisfactory on the lighter soils provided the seed was covered Good stands were also obtained merely by drilling in the seed on an unprepared seedbed Burning the stubble is not advisable Late fall seeding (September and early October), shortly before the soil freezes, gave better results than spring planting

The species recommended for depleted mountain and northern plains areas of the Arid Transition and Upper Sonoran life zones (*49*) are listed in Table 12

Although smooth brome is a broadly useful plant in this region, crested wheatgrass ranks first Introduced from Siberia about 1930,

Some valuable native species that spread by stolons or rhizomes tend to have weak seed habits or short seed stalks that make seed collection difficult. Buffalo grass is difficult to plant because of (1) lack of seed-

TABLE 11

SPECIES AND POUNDAGE OF SEED PER ACRE FOR DIFFERENT SITES IN THE SOUTHERN GREAT PLAINS REGION

Species	*Average Purity of Seed*	*Pounds of Seed per Acre for Different Mixtures* First	Second	Third
Summer (Warm-Season) Grasses for Heavy or Semiheavy Upland Soils				
Blue grama	40	8	6	7
Side-oat grama	20	3	3	3
Buffalo grass	85	2	2	2
Switchgrass	70	—	1	—
Weeping lovegrass	90	—	—	0.5
Summer Grasses for Sandy or Semisandy Upland Pastures				
Blue grama	40	5	5	3
Side-oat grama	20	7	7	6
Switchgrass	70	3	2	2
Sand lovegrass	80	—	1	0.5
Sand bluestem	25	—	—	5
Summer Grasses for Bottom Land Pasture or Hay, also for Uplands in Eastern Part				
Switchgrass	70	10	5	3
Side-oat grama	20	5	—	—
Indian ricegrass	60	—	5	5
Bluestems	25	—	5	5
Purple top	65	—	—	2
Winter (Cold-Season) Grasses for Grazing on Medium Heavy Upland Soils				
Bluestem wheatgrass	80	12	8	7
Canada wild rye	70	—	3	—
Texas bluegrass	50	—	1	2
Grasses for Irrigated Pasture or Hay				
Switchgrass	70	10	5	5
Side-oat grama	20	5	—	5
Bluestems	25	—	5	5
Indian ricegrass	60	—	5	5
Purple top	65	—	2	—

collecting machinery and (2) dormancy of seed (*44, 45*). These handicaps have now been partly overcome by development of several types of seed-collecting machines with suction or beaters to get the seed from the short stalks, and by treatments of the seed to over-

areas were large enough to constitute management units where proper standards of range use or the longevity of the stand could be determined. For these and other reasons the more or less unbridled optimism expressed by some reseeding specialists seems unjustified. Some livestock operators have indicated little interest in fostering native stands of forage to the fullest extent, since, according to the recommendations of some investigators, their lands could be cheaply regrassed with better vegetation.

Cost and return records on reseeding are most complete in the Intermountain region (Fig. 53, III) where Pearse and Hull (*37*) analyzed twelve areas. The cost of reseeding varied from about $1.81 to $4.50 per acre, whereas grazing and yield figures ranged annually from $0.35 to $0.54 per acre. After allowing for protection from grazing for 2 successive years after seeding, the increased forage had possibilities of offsetting total reseeding cost after 7 to 9 years of grazing use. In addition, certain intangible benefits should be recognized, such as improvement of watersheds, better balance of yearlong forage, and increased profits from the stock (*36*).

Even though empirical trials have demonstrated that various sites can be reseeded, private owners and public agencies have revegetated only very small portions of the depleted areas. Many operators and land managers are skeptical of reseeding partly because exaggerated claims for its success contrast sharply with the many failures of which they have observed or heard. Nowhere should reseeding be regarded as a panacea for overgrazing and other forms of mismanagement of the range. Additional data on reseeding costs, longevity of the stand, proper standards of use of reseeded areas, and certain other facts are obviously needed.

For further information on reseeding, the reader should consult the *1948 Yearbook of Agriculture*, entitled *Grass*.

Establishment of Irrigated Pastures

Discussing artificial reseeding on arid western range lands would not be complete without consideration of the establishment of irrigated pastures. Where this is possible, a few acres of irrigated pasture may be relied on to carry the animals through an otherwise short feed period.

An irrigated pasture is an area that is used primarily for grazing livestock and secondarily for production of hay. The land is prepared for application of irrigation water and then artificially seeded, usually to grasses and legumes. Areas not suitable for growing cultivated

it is now producing fairly good stands on some 1,250,000 range acres in Montana (*34*) and is suited to plains conditions as far south, incidentally, as the Panhandle of Texas Crested wheatgrass starts growth earlier in the spring than most grasses and is ready for grazing 2 to 4 weeks before the native pasture. Also, its grazing capacity is higher than that of many other species. It provides good feed for the lambing and calving period and endures close spring grazing (*56*).

Of some 24 strains of crested wheatgrass tested in Montana, "Fairway" is best in the intermediate mountain country that receives 15 to 20 inches of precipitation, whereas "Standard" is best in the plains region of lighter rainfall.

For erosion control and soil building, the following species are useful in the various areas of this region:

Alfalfa	Canada bluegrass	Little bluestem
Alkali dropseed	Crested wheatgrass	Needle-and thread
Arizona fescue	Desert willow	Quackgrass
Blowout grass	Hairy grama	Saltbushes
Blue grama	Indian ricegrass	Sudan grass
Bluestem wheatgrass	Kentucky bluegrass	Switchgrass
Buffalo grass	Lehmann lovegrass	Winterfat

Economic Aspects of Artificial Range-Land Reseeding

In the farm region of the humid East the balance between cost of artificially establishing a pasture cover and the returns in meat or milk production is generally so favorable that the economics of the operation is not questioned. Even when fertilizers are added, the cost of pasture reestablishment is economically sound.

In contrast, on the arid western ranges the cost of establishing a forage stand by artificial reseeding may be in close balance with the value of the increase in forage. Often such reseeding is only partially successful and will not justify the expense, or it is an outright failure. The economic outcome hinges largely on what sites are chosen, what plant species are used, how the seedbed is prepared and seeded, and how the area is managed. Certainly the more productive and moister areas should be reseeded first, after that one might chance, in a small way, seeding of the predominantly bleaker, more exposed sites, using the most xeric species and the most suitable planting techniques for such lands. Mountain meadows and deserted dry farms, as in the Great Plains region, have been reseeded most successfully.

Reseeding costs and long-time returns of resulting forage have been recorded on only a relatively few localities in the West. Few reseeded

cent of the total cash and labor cost is for water and irrigation labor. The cost of water is highest where it is pumped.

Selection of Species and Time of Seeding

A forage mixture of grasses and legumes, preferably composed of 4 to 6 species, gives the best results. Where water is available for only part of the season, or where irrigation intervals must be far apart,

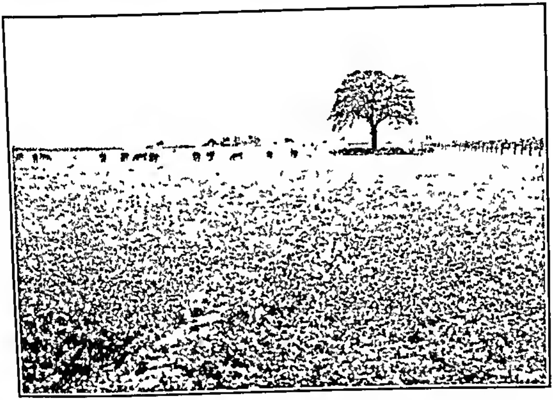

Fig. 56. Beef cattle on a paddock of irrigated pasture in California seeded to Ladino clover, meadow fescue, perennial ryegrass, and orchard grass. Note the presence of "strip-checks" to facilitate irrigation. The grazing capacity of irrigated pastures in California ranges from 5 to 20 animal unit months to the acre per year; total cost per animal unit month ranges from about $2.50 to $3.50. Sacramento County, 1949.

drought-enduring species should be used. Where adequate water is available forage species with different seasonal growth periods should be selected to prolong the succulent feed period.

Hamilton and associates (*21*) have recommended seed mixtures for different sites in each of the five climatic regions of the West (Fig. 53), as listed in Table 13. Information on additional seed mixtures can be obtained from the local county agent and other agricultural agencies.

Time of seeding is essentially the same as for the arid range. On a well-prepared seedbed, and with assurance of ample moisture, late summer or early fall seeding has some advantages over spring seeding.

crops can sometimes be profitably converted to irrigated pasture. Establishment is also often warranted on comparatively high-priced land where water is available at reasonable cost.

Land Capability Aspect

The most suitable acreage of irrigated pasture will depend on the number of livestock handled, the availability of cheap range forage, and the area of land that can be irrigated profitably. Lands suitable for irrigated pastures vary from level, highly productive areas—those capable of growing all locally adapted crops—to those that can only occasionally be cultivated. Steep slopes should be avoided, whereas gently sloping areas are eminently satisfactory, provided the soil is fairly deep and capable of fair water retention. Soils of low water-holding capacity require too frequent irrigations to make the practice profitable (*21*, *25*, *26*).

Methods of Irrigating

The purpose of irrigation is to moisten the soil root zone. Where the soil is easily eroded, water must be applied with care until the forage stand is established.

The method of irrigation adopted is determined chiefly by the soil type, presence of stones or outcrop, slope of the land, and the availability of water. Smooth to slightly rolling lands are conveniently laid out for "strip check" or "border" irrigation (*26*) similar to that used on alfalfa fields (Fig. 56).

Where the presence of rocks or excessive slope precludes leveling of the land for strip or border irrigation, controlled flooding may be advisable. To avoid destructive erosion, a ditch of moderate grade should conduct the water to the higher level of the field from where it is released.

Sprinkling is the most efficient method of pasture irrigation, but the initial cost limits its use. Sprinkling is especially recommended on rolling lands and on soils of low water-holding capacity, such as light sandy loams. It is also a suitable method where the water supply is limiting or the soil is too shallow to be levelled for border irrigation.

Regardless of the method of irrigation, the amount of water and the frequency of its application vary according to the climate, soil, and cover. Most pastures need about 2 acre inches per irrigation, the desired interval between irrigations ranges from 7 to 18 days. Sandy soils require more frequent but lighter water applications than loams or clays. Overirrigation should be avoided, because it is wasteful of water and may injure the cover. Usually more than 50 per

TABLE 13 — *Continued*

Intermountain Area (III)	Pounds per Acre
Well-drained soil	
Smooth brome	6
Orchard grass	4
Tall fescue	6
Ladino or white clover	2
Red clover	3
Total	21
Poorly drained soil, moderately alkaline or nonalkaline	
Smooth brome	6
Tall fescue	6
Strawberry clover	3
Total	15
Areas where irrigation water is not plentiful	
Smooth brome	6
Crested wheatgrass	4
Alfalfa	5
Total	15

Central Valleys of California and Southwest Areas (IA and IV)	Pounds per Acre
Well-drained soil:	
Perennial ryegrass	2
Dallis grass	4
Orchard grass	4
Ladino clover	2
Alfalfa	3
Total	15
Poorly drained, moderately alkaline or nonalkaline soil	
Dallis grass	4
Rhodes grass	6
Strawberry clover	3
Sweetclover	2
Total	15

Great Plains Area (V)	
Alfalfa	4
Smooth brome	14
Total	18

left ungrazed during the late fall and winter. The accumulated growth protects the cover in the winter and induces early vigorous spring pasturage.

Bloat Control

Bloat among cattle and sheep is often troublesome where legumes, particularly alfalfa, constitute a large part of the stand. The cover should consist chiefly of grass, with alfalfa or other legumes composing not more than about 30 percent of the stand. It is good practice to have hay or straw available to animals that are grazing upon pasture composed largely of legumes. Where bloat is serious, pastures containing chiefly legumes should be allowed to reach a fairly advanced growth stage before admitting the stock. Bloated animals can sometimes be saved by treating with some antiferment, such as ½ ounce

Drilling in the seed is preferable to broadcasting, just as on the open range. Where the seed is broadcast the soil should be packed with a roller before and after scattering.

Managing Irrigated Pastures

Careful management is requisite to maintaining desirable plant composition. Pastures seeded in summer or fall should not be grazed until the following summer and spring-seeded areas not until autumn. Grazing should be moderate at all times, and stock should be kept off when the soil is wet. Where an excess of forage is produced it may be mowed at least once a season.

Rotation grazing is essential. It provides short rest periods and tends to maintain high plant vigor and maximum yield. The ideal practice is to divide the pasture into three or four paddocks so the animals may be rotated from one unit to the other as the surface soil becomes firm after irrigation and the forage growth advances.

Seasonal resting of irrigated pastures is beneficial. The pasture is

TABLE 13

Seed Mixtures for Five Climatic Regions of the West

Northern Pacific Coast Area (1B)	*Pounds per Acre*
Well-drained soil	
Perennial ryegrass	2
Orchard grass	4
Tall fescue	6
Ladino clover	3
Red clover	3
Total	18
Poorly drained, heavy textured soil	
Tall fescue or	8
Meadow foxtail	6
Ladino clover	3
Total	9 or 11

Southern Pacific Coast Area (1A)	*Pounds per Acre*
Well-drained soil	
Perennial ryegrass	2
Orchard grass	4
Tall fescue	6
Ladino clover	3
Total	15
Poorly drained soil, moderately alkaline or nonalkaline	
Central California	
Italian ryegrass	2
Tall fescue	6
Alsike clover	2
White clover	2
Total	12
Southern California	
Dallis grass	4
Rhodes grass	6
Strawberry clover	2
Sweetclover	2
Total	14

preferable. When they are once started on a legume pasture, it is better to keep the animals there day and night rather than removing them at night (*25*).

Artificial Reseeding of Eastern Farm-Pasture Province

The more strictly farm-pasture province, lying slightly east of the 100th meridian, is divided into two climatic units: the East Central and Northeast region, and the Southeastern region (Fig. 53, VI and VII).

VI. East Central and Northeastern Region. The northern and eastern portion of this region lies mainly in the Humid Transition life zone, whereas the central portion is in the Upper Sonoran zone. The original vegetation of most of the region has been replaced by introduced forage plants. Maximum productivity of the perennial pastures depends chiefly on three factors: season of use, application of fertilizers, and adaptability of species to different sites (*8*, *48*). Too early spring grazing weakens palatable forage and induces weediness. Top dressings of limestone in the heavier precipitation areas and applications of phosphorus over extensive units sharply increase the forage yield and extend the life of pasture in this region. Cultural practices with sodbound grass, such as disking or harrowing, have given disappointing results.

Despite the care given, pastures in this region must be replowed and reseeded every few years. The success of this undertaking is much influenced by the way the seedbed is prepared. On the stronger sites, plowing, harrowing, fertilizing (where needed), and rolling before seeding give best results. Spring or early summer seeding is generally recommended.

The species used for seeding are mainly of European origin. Semple and associates (*48*) recommend seed mixtures according to quality of site, as shown in Table 14.

In the northern part of this section, Korean lespedeza should be used; in the southern part, common, kobe, or Tennessee 76 are best. Kobe and Tennessee 76 are usually more productive than common, but good results are obtained from a mixture of common and Korean in Tennessee and North Carolina.

For erosion control and soil building in this general region, the following species have been used most:

Canada bluegrass	Sheep fescue
Kentucky bluegrass	Smooth brome
Orchard grass	Sudan grass
Reed canary	White clover
Redtop	

of formalin or 1 ounce of turpentine in a drench Mix formalin with water and turpentine with milk In severe cases, puncture the distended stomach with knife or trocar Doctoring bloated animals, however is an unsatisfactory proposition, and prevention is always

handled crop, has had at his disposal merely the original wild forage plants and a few introduced domesticated species. Pasture plant breeding in North America was started not many years ago and only on a small scale but is now receiving much deserved attention from both Federal and state agencies (*20*).

Improvement in plants is accomplished in two ways: (1) through selection of desirable forms that occur in nature, or (2) from hybridization to secure new combinations from which selections may be made.

Selection

Breeding of plants by selection perpetuates, through conscious choice by man, one or more desirable characters encountered in a mixed population. It is the oldest and most widely employed method of plant improvement, and it helped develop most of our field, garden, and orchard crops as well as our animal breeds. Selection has resulted, among other things, in obtaining greater size, yield, adaptability, and hardiness of many plants and animals.

In working with native plants it is important to recognize the selective effect of the environment. In each climatically diverse environment there exist races of plants that are peculiarly well fitted to survive. These climatic races are now receiving some recognition in artificial reseeding studies. The fitness of the so-called ecotypes and ecospecies[5] to meet the conditions of the environment is largely a matter of genetically determined physiological processes. The physiological requirements for successful maintenance of a plant in a given habitat are many and fairly exacting. Small differences, for example, in the average seasonal temperature or in the frost-free growing season may result in appreciable shift in the genetic composition of a natural plant population.

Under cultivation it has been possible to preserve the more desirable plant characters merely by selecting and planting the most suitable individuals. Selection of various domesticated pasture and hay plants for use on restricted meadows has also given good results (*14*). Because of the mixed plant population on natural open range, selection has not been effective because of the difficulty of maintaining the improved forms. Under such conditions hybridization seems more hopeful of permanent stand improvement.

[5] An ecotype is a subspecific plant unit composed of genetically distinct races, whose population has become adapted to a relatively restricted habitat. An ecospecies is a plant unit composed of one or more ecotypes, and which generally corresponds to a species in a taxonomic sense.

VII Southeastern Region Units *A* and *B* of Region VII (Fig 53), treated together, differ in that unit *B* is frost-free whereas unit *A* is not Several species are grown successfully in both units, but in *B* strictly tropical forage plants do best

The most critical period for livestock grazing is in the winter when the native grass of forest and glade is of low quality (*5*) The forest ranges for spring and summer grazing alternated with pasture of domesticated forage plants in fall and winter provide fairly satisfactory yearlong feed

Both temporary and permanent artificially seeded pastures are used in both units for winter feed The temporary pastures are seeded to various cereal grains and such legumes as crimson clover, vetch, lespedezas, and velvet bean (*39*)

Over much of the South the more permanent pastures are commonly seeded to mixtures such as those in Table 15 (*48*)

TABLE 15

SPECIES RECOMMENDED FOR SEEDING IN SOUTHEASTERN REGION

On Moist, Sandy Soils	*Pounds per Acre*	On Clay, Loam or Silt Soils	*Pounds per Acre*
Carpet grass	5–6	Bermuda grass*	5–6
Dallis grass	3–4	Dallis grass	3–4
Lespedeza	12–15	Lespedeza	10–12
Total	20–25	Total	18–22

* Bermuda grass is usually started by setting out pieces of sod

In the extreme frost free southern part of unit *B*, such tropical species as Bahia, Guinea, molasses Napier or elephant grass para, and St Augustine grasses are popular, especially on the mulch soils

For erosion control and soil building, the following species are recommended

Alfalfa	Dallis grass
Annual lespedezas	Hop clover
Bermuda grass	Johnson grass
Broomsedge	Kudzu
Carpet grass	*Lespedeza sericea*
Centipede grass	Velvet bean

Spring seeding on a well prepared seedbed gives the best results

Improvement of Forage Plants for Reseeding

Unlike growers of fruits or cereals, who have long enjoyed the benefits of improved varieties, the grazier, with his less intensively

Annual lespedezas (*Lespedeza* spp.)
Arizona fescue (*Festuca arizonica*)
Astoria bentgrass (*Agrostis tenuis* var. *astoriana*)
Australian saltbush (*Atriplex semibaccata*)
Bahia grass (*Paspalum notatum*)
Bearded wheatgrass (*Agropyron caninum*)
Beardless wild-rye (*Elymus triticoides*)
Bermuda grass (*Cynodon dactylon*)
Big bluegrass (*Poa ampla*)
Big bluestem (*Andropogon girardi*)
Big mountain brome (*Bromus marginatus*)
Birdsfoot trefoil (*Lotus corniculatus*)
Black grama (*Bouteloua eriopoda*)
Blowout grass (*Redfeldia flexuosa*)
Blue grama (*Bouteloua gracilis*)
Blue wild-rye (*Elymus glaucus*)
Bluebunch wheatgrass (*Agropyron spicatum*)
Bluestem (*Andropogon* spp.)
Bluestem wheatgrass (*Agropyron smithii*)
Boer lovegrass (*Eragrostis chloromelas*)
Broomsedge (*Andropogon virginicus*)
Buffalo grass (*Buchloe dactyloides*)
Bulbous bluegrass (*Poa bulbosa*)
Bur clover (*Medicago hispida*)
Burnet (*Sanguisorba minor*)
Bush muhly (*Muhlenbergia porteri*)
Cacti (*Opuntia* spp.)
California brome (*Bromus carinatus*)
California oatgrass (*Danthonia californica*)
Canada bluegrass (*Poa compressa*)
Canada wild-rye (*Elymus canadensis*)
Carpet grass (*Axonopus compressus*)
Centipede grass (*Eremochloa ophiuroides*)
Cereal rye (*Secale cereale*)
Chamiza (*Atriplex canescens*)
Chewings fescue (*Festuca rubra*)
Cholla (*Opuntia* spp.)
Common lespedeza (*Lespedeza striata*)
Creeping bent (*Agrostis palustris*)
Crested wheatgrass (*Agropyron cristatum*)
Crimson clover (*Trifolium incarnatum*)
Curly mesquite (*Hilaria belangeri*)
Dallis grass (*Paspalum dilatatum*)
Desert willow (*Chilopsis linearis*)
Elephant grass (*Pennisetum purpureum*)
Filaree (*Erodium* spp.)

Hybridization

The union of opposing sexes each of a different variety, species, or genus constitutes hybridization The resulting offspring inherit traits of both parents Descendents of the cross are selected to produce a uniform type, that is a combination of the most desirable parental features Standard procedure in hybridization and selection appears to offer good possibilities of improving range grasses and other organisms though not without some difficulties

Fertility of hybrids may vary from a high percentage, when closely related races are used, to total sterility when remote species are crossed This behavior may be explained on the basis of chromosomal incompatability In some cases the somatic chromosome complement (complete set of chromosomes carried by each body cell) has been doubled by the use of colchicine[6] and other chemicals, resulting in completely fertile polyploid forms termed amphidiploids To date, however, few of these have had any practical value Some cultivated plants have been increased in size, vigor, and otherwise as a result of increase in the number of chromosomes contained in the cell nucleus The possibility of obtaining true breeding strains of range grasses through doubling or twice doubling of the chromosomes of segregating hybrids is largely unexplored

The outlook for improvement of range grasses seems promising Clearer understanding of the genetics of size, growth, and form of the organism and its parts should point the way to a more effective approach to range forage improvement (2)

Plants Mentioned for Reseeding

Alfalfa (*Medicago sativa*)
Alfilaria (*Erodium* spp)
Alkali dropseed } (*Sporobolus airoides*)[7]
Alkali sacaton }
Alsike clover (*Trifolium hybridum*)
Alta fescue (*Festuca arundinacea*)

[6] Colchicine is a toxic alkaloid obtained from the bulb of *Colchicum autumnale* It has the remarkable property of changing chromosome distribution in the cell nuclei of plants to produce new varieties The use of colchicine in genetic or cytological studies is still in the experimental stage with results unpredictable The drug is effective only in the growing region of the plant hence an aqueous solution is most commonly applied to seeds seedlings expanding buds or bulb scales Other treatments or manipulations of plant parts that react more or less like colchicine are indole butyric acid x ray and exposure to heat and cold

[7] *Sporobolus airoides* is known as alkali dropseed in some localities and as alkali sacaton in others

Rhodesgrass (*Chloris gayana*)
Rose clover (*Trifolium hirtum*)
Rothrock grama (*Bouteloua rothrockii*)
Ryegrasses (*Lolium* spp)
Sacaton (*Sporobolus wrightii*)
St Augustine grass (*Stenotaphrum secundatum*)
Saltbush (*Atriplex* spp)
Sand bluestem (*Andropogon hallii*)
Sand dropseed (*Sporobolus cryptandrus*)
Sand lovegrass (*Eragrostis trichodes*)
Sandberg bluegrass (*Poa secunda*)
Seaside bent (*Agrostis palustris*)
Sheep fescue (*Festuca ovina*)
Slender wheatgrass (*Agropyron trachycaulum*)
Smilo (*Oryzopsis miliacea*)
Smooth brome (*Bromus inermis*)
Soft chess (*Bromus mollis*)
Stiff-hair wheatgrass (*Agropyron trichophorum*)
Strawberry clover (*Trifolium fragiferum*)
Streambank wheatgrass (*Agropyron riparium*)
Subterranean clover (*Trifolium subterraneum*)
Sudan grass (*Sorghum sudanense*)
Sweetclover (*Melilotus* spp)
Switchgrass (*Panicum virgatum*)
Tall (alta) fescue (*Festuca arundinacea*)
Tall meadow oatgrass (*Arrhenatherum elatius*)
Tanglehead (*Heteropogon contortus*)
Tennessee 76 (var of common lespedeza, *L stipulacea*)
Texas bluegrass (*Poa arachnifera*)
Thickspike wheatgrass (*Agropyron dasystachyum*)
Timothy (*Phleum pratense*)
Tobosa (*Hilaria mutica*)
Velvet bean (*Stizolobium* spp)
Velvet grass (*Holcus lanatus*)
Vetch (*Vicia* spp)
Violet wheatgrass (*Agropyron pauciflorum*)
Vine-mesquite (*Panicum obtusum*)
Weeping lovegrass (*Eragrostis curvula*)
Western wheatgrass (*Agropyron smithii*)
White clover (*Trifolium repens*)
White sweetclover (*Melilotus alba*)
Wild oats (*Avena* spp)
Wimmera ryegrass (*Lolium rigidum* var *strictum*)
Winterfat (*Eurotia lanata*)
Yellow sweetclover (*Melilotus officinalis*)

Flat pea (*Lathyrus sylvestris* var. *wagneri*)
Foothill needlegrass (*Stipa lepida*)
Fourwing saltbush (*Atriplex canescens*)
Galleta (*Hilaria jamesii*)
Greenleaf fescue (*Festuca viridula*)
Guinea grass (*Paspalum maximum*)
Hairy grama (*Bouteloua hirsuta*)
Harding grass (*Phalaris tuberosa* var. *stenoptera*)
Highland bentgrass (*Agrostis tenuis* var.)
Hop clover (*Trifolium procumbens*)
Idaho fescue (*Festuca idahoensis*)
Indian ricegrass (*Oryzopsis hymenoides*)
Intermediate wheatgrass (*Agropyron intermedium*)
Italian ryegrass (*Lolium multiflorum*)
Johnson grass (*Sorghum halepense*)
Junegrass (*Koeleria cristata*)
Kentucky bluegrass (*Poa pratensis*)
Kikuyu (*Pennisetum clandestinum*)
King ranch bluestem (*Andropogon ischaemum*)
Kobe lespedeza (var. of common lespedeza, *L. striata*)
Korean lespedeza (*Lespedeza stipulacea*)
Kudzu (*Pueraria thunbergiana*)
Ladak alfalfa (*Medicago sativa* × *M. falcata*)
Ladino clover (*Trifolium repens*)
Lehmann (mat) lovegrass (*Eragrostis lehmanniana*)
Lespedeza (*Lespedeza* spp.)
Little bluestem (*Andropogon scoparius*)
Meadow foxtail (*Alopecurus pratensis*)
Mesa dropseed (*Sporobolus flexuosus*)
Mat lovegrass (*Eragrostis lehmanniana*)
Molasses grass (*Melinis minutiflora*)
Mountain brome (*Bromus carinatus*)
Napier grass (*Pennisetum purpureum*)
Needle-and thread (*Stipa comata*)
Needlegrass (*Stipa* spp.)
Orchard grass (*Dactylis glomerata*)
Para grass (*Panicum purpurascens*)
Perennial ryegrass (*Lolium perenne*)
Pubescent wheatgrass (*Agropyron trichophorum*)
Purple needlegrass (*Stipa pulchra*)
Purple top (*Triodia flava*)
Quackgrass (*Agropyron repens*)
Red clover (*Trifolium pratense*)
Redtop (*Agrostis alba*)
Reed canary (*Phalaris arundinacea*)

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Chapter 12

NATURAL RESEEDING AND SYSTEMS OF GRAZING ON WESTERN RANGES

Where most of the native forage crop has been destroyed in the open range country, artificial reseeding provides the only expeditious means of revegetation. But, fortunately, over the greater part of the western range region depletion has not been carried to a point where all the better forage plants have been destroyed. These tracts can be so handled as to bring about effective natural revegetation.

General Considerations

Natural revegetation (reseeding) is the restoration of depleted ranges by manipulating the grazing season in a way that will favor reproduction of the remaining desirable native or naturalized forage species. It can be done on all ranges where a sufficient cover of the better forage plants remains to produce adequate seed for revegetation under favorable grazing practices.

On large-scale operations natural reseeding with an adapted plant cover is less expensive and often more effective than artificial planting. Accordingly, artificial planting should not be undertaken where natural reseeding is practicable. Forsling and Dayton (*9*) concluded:

> Where there is already a fair stand of palatable and nutritious natural vegetation it will not pay to attempt plant introduction. Even where the natural vegetation has been badly depleted, but a few seed plants remain, it is usually more economical to increase the forage by so handling the range that it will improve naturally.

The chief causes of depletion of the forage cover (Fig. 57) are too early spring grazing and overly close cropping during the normal grazing period. Continuous, early spring grazing results in depletion almost directly proportional to the intensity of the pasturing; but a single cropping at that season is not necessarily harmful (*14, 15*). Where the grazing animals are held on the spring range until the summer

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were sent up and more viable seed was produced than on adjacent range that was grazed early and repeatedly. The vigor of the vegetation is a vital factor in determining the time of seed maturity, the size of the seed crop, and its viability.

The seeds of most forage plants are dropped soon after they mature. Grazing at this time is especially desirable, since little of the seed crop is available for livestock and trampling by the animals results in satisfactory planting. Since grazing is the sole controllable factor, an area that is being revegetated should be utilized with minimum injury to plant cover and litter (*11*).

Revegetation Under Different Grazing Systems and Practices

Not all of the various grazing practices of the West favor natural revegetation. The six more common range-management practices are: yearlong (season-long) grazing, yearlong protection from grazing; the Hohenheim system, the deferred-grazing system; the rotation-grazing system; and the deferred-rotation system.

Yearlong (Season-Long) Grazing

The practice of maintaining the animals on the same pasture throughout the season or year is rather common. The pasturage gets rest from the grazing strain only insofar as the livestock may keep but a portion of the forage continuously grazed down. In early spring the forage of the entire area may be kept closely cropped. As the rapid summer growth cycle approaches, the animals are unable to graze all the forage; they consume the more palatable species, usually leaving those of lower or no forage value to reseed. In the autumn the more accessible areas are often devoid of good forage, for the animals tend to leave only inaccessible, inferior portions of the range with usable growth. Yearlong use of a pasture, with little or no effort to guide the stock to the areas most suitable for grazing as the season advances, is the cause of serious range deterioration (*1, 18*). Indeed, even when a depleted area is grazed lightly throughout the growing season, practically all the better forage plants are usually cropped too closely to regain full vigor (*8*). Unless a unit is so conservatively stocked as to leave a goodly portion of seed stalks uncropped, yearlong or season-long grazing will not result in revegetating depleted areas.

Yearlong Protection

Since ranges may suffer from season-long use, it might be assumed that depleted areas would benefit most by complete protection from grazing during the growing season. This is not always true. Peren-

area is ready for use, alternate portions of the range should be grazed early in the spring in different years, thus allowing time for each division to recover from the strain of early season pasturing. Also, during early spring the soil is often saturated with moisture and may be injured by excessive trampling. At such times the animals

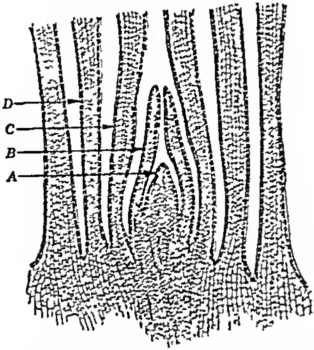

FIG 57. Longitudinal section of a segment of bluebunch wheatgrass (*Agropyron spicatum*) in early spring *A*, Leaf bud, *B*, young leaves about to ascend from the ground, C and *D*, older leaves. Excessively close spring grazing by sheep is likely to injure grass buds.

should be grazed on well-drained areas. The effects of trampling and pulling out of the plants may at times be more detrimental than close cropping of the herbage.

Moderate grazing after the forage stand has attained fair growth is not injurious; indeed, such grazing is preferable to nonuse. In a natural reseeding program the late grazing season should receive special consideration.

The production of a large, vigorous seed crop is the most important means by which forage plants reproduce and revegetate the range. The amount of viable seed produced varies directly with the intensity of grazing. For example, Sampson (*13*) found that when greenleaf fescue (*Festuca viridula*) was protected from grazing until the seed crop had ripened, a larger number of earlier and stronger flower stalks

restoring most western ranges It is broadly applicable and inexpensive (Fig. 58). Although originally and specifically applied and adapted to perennial bunchgrass ranges of the high mountains, the principles, through the application of semideferred grazing, may also

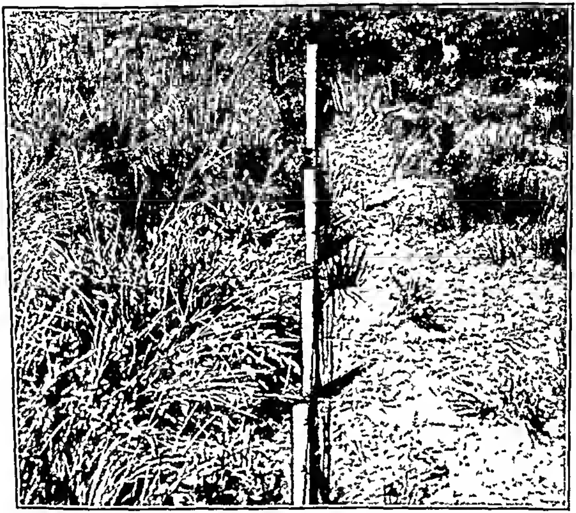

Fig 58 Deferred grazing on a bunchgrass range in eastern Oregon. *Left*, area where deferred grazing has been practiced has resulted in good revegetation of all species, *right*, area closely grazed and declining in forage production.

be used on a combination of annual and perennial vegetation and on the more strictly annual-plant cover, such as the "winter-annual" ranges of California.

On Perennial Mountain Bunchgrass Range. Since the deferred grazing system takes into account the growth and seed-producing requirements of the vegetation, it gives the palatable plants practically as good a chance to reproduce as the unpalatable forms The mature forage is consumed well on most deferred-grazed perennial bunchgrass ranges, the semicured vegetation may be expected to maintain the animals in fair to good flesh.

nial bunchgrasses and sodformers become more vigorous and increase in vegetative growth under season long protection, but relatively few seedlings may become established without livestock to trample the seed into the ground. Species that do increase, such as filaree (*Erodium*), needlegrass (*Stipa*), and three awns (*Aristida*), are chiefly those whose hygroscopic awns result in planting of the seed. Seeds having short awns or species with large, awnless seeds are likely not to get planted. Moreover, the loss of one or more seasons of forage growth during the total rest period is wasteful. Also, the accumulation of inflammable dry grass may constitute a serious fire menace. Protected plots have shown that weeds soon replace the matted accumulation of grass, thus defeating the purpose of total exclusion of stock. However, partial seasonal rest is highly beneficial on most natural ranges and tame pastures but will not always result in establishment of new plants by reseeding.

Hohenheim Grazing System

This system of pasture management is the must intensive of modern pasture practices and is especially adapted to irrigated and tame pastures (*21*). It originated near Stuttgart, in western Germany, about 1918, when there was a shortage of concentrates and munition plants were converted to production of cheap nitrate fertilizers. The system aims at supplying a luxuriant growth of grass rich in protein.

Nitrate dressings are heavily applied to the pasture lands. The pasture is fenced into several units and the animals remain only lung enough in any one unit to graze the forage lightly. When the stocker animals are removed, the remaining forage is mowed, and another dressing of nitrate fertilizer is supplied.

The Hohenheim system is more suited to western Europe than to the United States. But the plan has been partially adapted in irrigated sections, as on Ladino clover areas in California. Its success depends upon maximum production of the existing plant cover and is not designed to revegetate depleted areas, which it does not accomplish.

Deferred-Grazing System

This system consists of reserving part of the range area until *after seed maturity*. The acreage reserved must be large enough to carry all the animals from the time of seed maturity of the primary forage species to the end of the normal grazing season (*14*). Deferred grazing provides for revegetating one unit of a range allotment at a time until the entire area has been reseeded. The technique of revegetating the lands without loss of forage makes this the most practicable method of

The period of growth and of heavy precipitation is July, August, and September. Only during that period are the less valuable three-awn grasses (*Aristida* spp.) and dropseeds (*Sporobolus* spp.) palatable,

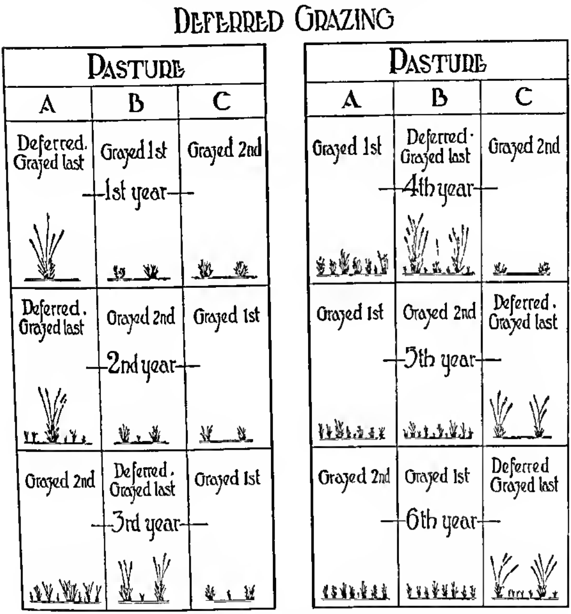

FIG. 59. Schematic sketch showing procedure, year by year, of deferred grazing leading to ultimate revegetation of an area as a whole.

whereas black grama retains its palatability and nutrition during the entire year. Accordingly, a grazing plan is desirable that will result in only light grazing of the black grama during the critical growing period while permitting utilization of those species that are valuable only in the summer. The semideferred-grazing system provides for light utilization during the summer, partially reserving the black grama

The acreage required for deferred grazing can be readily calculated Suppose that on an area of 1000 acres, the opening date of the grazing season is May 1 the date of seed maturity September 1, and the closing date of the grazing season October 15 The length of the grazing season (from May 1 to October 15) is 165 days, and the number of days from seed maturity to the end of the grazing season (September 1 to October 15) is 45 days Then 45/165 × 100 = 27 27 percent, which is the percentage of the area to be deferred Therefore, 272 7 acres (1000 × 27 27 = 272 7) are not grazed until after seed maturity for 2 years in succession, and then another area is deferred for 2 years This practice is continued until the entire 1000 acres have been reseeded

In addition to protecting the forage on the deferred-grazed area during its full growth cycle, ample livestock water must be available, since the forage is relatively dry when utilized Deferred grazing on unfenced cattle ranges can be accomplished, in part at least, by judicious salting, cross fencing, and water development The correct date for the opening of grazing season must be determined, the proper grazing capacity must be established, and local overgrazing should be corrected to the greatest extent possible In mountain country, differences in forage growth at the various elevations is taken care of by delaying the grazing until the vegetation in each zone is properly developed

Figure 59 shows how deferred grazing may be applied on a range area that is divided into three subunits *A*, *B*, and *C* In this example, subunit *A* is deferred grazed first for 2 years in succession, subunit *B* is grazed by deferment in the third and fourth years, and subunit *C* in the fifth and sixth years Grazing early in the season for 2 years in succession, such as indicated for subunit C in the second and third years or subunit *A* in the fourth and fifth years, can usually be avoided by observing the extent of revegetation of the other two subunits and shifting the stock accordingly However, the importance of deferring the grazing for 2 successive years and of protecting the seedlings on the deferred grazed unit by moderately late cropping in the third year must not be overlooked

On perennial mountain bunchgrass ranges, in particular, deferred grazing or some form of rotational cropping has proved virtually essential to their revegetation and maintenance

On Mixed Annual and Perennial Range In the Southwest where black grama predominates but where there are also abundant annual grasses, a so called semideferred grazing plan has been successfully used in conserving and increasing the valuable black grama (*Bouteloua eriopoda*) At the same time this plan procures seasonal use of the early maturing annual grasses and minimizes the effects of drought (5)

Although this assumption seems to hold in some localities or vegetal covers, it may not in others (*12, 21*)

Deferred Rotation System

It is difficult to visualize the adoption of either a deferred- or a rotation grazing system that does not to some extent involve the employment of both of these That is why the combination term deferred rotation is commonly used 'Deferred and "rotation" grazing will not be confused if one keeps in mind that deferred provides for delaying the grazing until after seed maturity, whereas rotation is applied without specific provision for seed production

Most rotation grazing systems as practiced on the western range are, in effect, deferred rotation systems, in which the primary forage species have good conditions for setting seed and getting it planted on one subunit each season On cattle range deferred rotation grazing is carried out by dividing the area into appropriate subunits by fencing or taking advantage of natural boundaries, on open sheep range it is accomplished by herding so as to rotate the grazing from one subunit to another

Where deferred rotation grazing is practiced, the larger number of animals necessarily placed on each subunit periodically results in fairly close and uniform grazing due to the reduced size of the area and the relative closeness to water and salt It follows that under this system better livestock distribution is assured than under a continuous grazing system, which involves a correspondingly larger acreage If the stocking rate of the rotation grazed subunits is correct, proper utilization is also more likely, and improvement in the cover of the more depleted portions may be expected In the Pacific Northwest Frandsen (*10*) reported that deferred rotation grazing has given highly satisfactory results in reseeding and maintaining the cover In this region of winter rainfall prevention of range deterioration is difficult under season long grazing practice

Studies reported by Black and Clark (*4*) in western South Dakota showed no appreciable change in the vegetation on the continuously versus alternately grazed pastures after 4 years Under both systems the stocking rate was moderate, and the alternate pastures were grazed 28 days and rested for a similar period Also, there was no significant difference in cattle weights from these grazing systems On the other hand, Sarvis (*19*), and Clarke, Tisdale and Skoglund (7) reported that where grazing was rotated the vegetation was improved over that on the continuously grazed pastures, however, the weights of the cattle or weaner calves were somewhat greater on the conservatively stocked

for later use Thus the annual grasses are not wasted, and the black grama is not cropped excessively during the critical period of growth, hence stands that are thinning out may effectively be revegetated if the range is not overstocked

On "Winter-Annual" Range Where deferred or semideferred grazing is applied to ranges of winter growth, such as in California, special seasonal uses and semiprotective intervals may be adopted (2) The aim is chiefly to increase seed production Most annual forage plants produce abundant seed even when grazed for several weeks early in the spring

On the foothills of California, for example, seed is produced where the spring grazing continues up to about March 15 When the deferred grazing plan is applied, the pasture is divided into some three units (*16*) The unit first to be deferred is grazed up to the period of most active growth, the animals being removed from about March 15 to June 1 To trample the newly formed seed into the ground and to utilize the forage growth this area alone is grazed from June 1 until about July 15, depending on the condition of stock and forage After such pasturing, the animals are allowed to graze the entire pasture Deficiencies in the forage are met by supplements fed during the fall and winter Then a second area is selected for deferment, and the grazing procedure is repeated until the entire range is revegetated Deferred grazing is less popular on ranges of annual growth than on those of perennial vegetation because the resulting denser stand of tall grasses tends to crowd out the shorter filaree and bur-clover Where the deferred pasture unit is properly utilized after seed maturity, it is doubtful that the population of broad-leaved herbs declines perceptibly

Rotation Grazing System

This technique, also called alternate grazing, consists of transferring the livestock systematically at suitable intervals during the growing season to different subunits of the range area and back to the first subunit *without specific provision for seed production* The aims are (1) to avoid cropping the same subunit early in the spring year after year, and (2) to maintain the forage cover over the entire range area in the highest possible vigor, with little or no decrease in animal production (*17*)

Any range unit or fenced pasture that has merely been divided into two subdivisions with a view to improving forage vigor is properly spoken of as rotation or alternate grazing The system assumes that intermittent rest from grazing is beneficial to the forage cover, even though it must support more stock during the shorter grazing period

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continuously grazed pastures These workers suggested that the beneficial effects of deferred rotation grazing are more evident in the restoration of overgrazed pastures than on ranges in a high state of productivity

In the southern Great Plains station at Woodland, Oklahoma Savage Brown and McIlvain (*20*) found that deferred rotation grazing gave higher livestock winter gains but lower summer and yearlong gains They concluded that grazing deferment is a desirable practice if it does not result in excessive grazing of one or more of the subunits

In the switch cane pastures of North Carolina Biswell and Foster (*3*) found no advantages from rotation grazing over continuous grazing

The ultimate objective of any grazing system should be to provide maximum high quality animal products per unit area on a long time basis consistent with perpetuating the forage resource The system that meets this objective should be employed whether it be moderate, continuous grazing deferred cropping or some form of deferred rotation grazing Range operators should adopt a grazing plan that is suitable to their particular conditions For assistance in this they should consult the local county agent or Federal range representatives

Cultivation of Range

Natural reseeding can be assisted by various means of cultivating the range The theory behind any cultural treatment is that soil packing will be overcome and some of the existing plants will be thinned out so that more moisture will be available for growth of the remaining plants Disking or harrowing of the range is occasionally done in late spring chiefly to stimulate the growth of old stands of sodgrasses Where such practice was followed it was found that cultural treatment by almost any means must be done with extreme care Carrier and Oakley (*6*) concluded that indiscriminate recommendation of cultural treatment of pastures is a serious mistake Perhaps one of the largest benefits derived is from breaking up and spreading manure droppings over the sward Other cultural treatments are those concerned with construction of contour trenches to control erosion and with water spreading both of which involve treatment of only a portion of the surface area

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CONTROL OF NOXIOUS WOODY VEGETATION ON RANGE LANDS

In parts of all continents forage production has declined because of encroachment of low-value woody vegetation

Fire is the oldest, most common, and perhaps the cheapest 'tool' for suppressing this undesirable growth Biological control, especially by browsing animals, may be used after burning Mechanical removal and spraying with chemical herbicides are also employed But fire will probably continue as the most common means of control, despite the danger of its escape to adjoining properties and the fact that burning of steep slopes often adversely influenees watersheds and may lower soil productivity (Chapter 23) Most of the discussion in this chapter concerns wild fires and controlled and prescribed burning What is the correct and accepted usage of these terms?

Wild fires or uncontrolled burning is promiscuous indiscriminate, or accidental burning of vegetation with no plan and no responsibility for damage to property resulting from escape of the flames

Controlled burning is the planned application and confinement of fire to preselected wildland areas The actual firing is done in so many ways that no clear-cut description can be made of all of them At one end of the scale of controlled burning techniques is the 'convenience fire where the only elements predetermined are time and place of the burn At the other extreme is the 'prescribed burn' plan

Prescribed burning provides for firing land when weather and condition of the vegetation allows ***a particular method of burning*** that will produce intensities of heat and rates of spread which should bring about expected or maximum benefits to soil and vegetation

Fire, properly employed, may serve man well, in the hands of the inexperienced, irresponsible, or uninformed it may cause great damage Because of the importance of recognizing the bad as well as the good effects on the soil and on the character of the vegetation of suddenly removing the cover, a brief resume of background considerations of burning is presented here

Some Background Considerations of Range Burning

Studies indicate that rational use of fire has a place in range management, but that too frequent and unseasonable burning—especially if followed by poor management—is bad practice.

The firing of a heavy plant cover may abruptly change the physical and biological conditions that existed before the burning. The firing of light-to-medium plant cover may have lesser immediate ecological effects than burning of heavy vegetation but may conspicuously lower soil productivity if burning is repeated frequently. It may alter vegetation, soil, and water cycle to a measurable degree, favorably or not. Therefore, unqualified generalizations as to the beneficial or harmful effects of burning, even locally, are risky in the extreme. Each individual area demands critical analysis if fire is to be used rationally.

Prehistoric Burning

Evidently fires have occurred ever since there was inflammable material on the earth's surface. Wood found in the Pleistocene formations "indicates the results of forest fires" (*44*). The charcoal of 2000- to 3000-year-old North American peat bogs, and the California big trees, supports the claims of fires in the distant past. Both lightning and man were responsible.

Catter (*11*) inquires:

> If man set fires annually in California and elsewhere (for example) for 100,000 years, what would be the effect on the vegetation, hence on the soil, and consequently on the plant and animal life?

Professor A. L. Kroeber, University of California anthropologist, presented the following views to the author:

> The Indians (of California) burned considerably in both open country and forest for various reasons. Burning was not indiscriminate but tended to be limited to certain tracts in which they were interested. In general, the Indians nowhere burned the chaparral with the idea of getting rid of it. A good stand of it is harder to get through after burning than before. If they fired the chaparral occasionally it was with the idea of driving the game out. Kroeber also affirmed that the aggregrate extent (of California lands) burned over occasionally or more or less regularly must have been considerable, but he expressed uncertainty as to whether burning in brushlands was extensive.

Burning of brushlands by Indians was probably on such a restricted scale that it could have influenced little, if at all, the present composition or distribution of the chaparral over the state. The major Indian

population was along the coastal slopes and in the valleys, away from the present distribution of the chaparral lands. Areas remote from the coastal and valley regions were apparently only slightly subject to directed or systematic burning. And it is probable, therefore, that at least a fair (if not the major) proportion of the fires reported by the early explorers at the higher elevations were started by lightning as they are today (*48*).

The study of Indian burning in California, although interesting, has little application in the current effort of brush control.

The American aborigines evidently brought the art of fire making with them from Asia (*31*). The late C. Hart Merriam, authority on the habits of the western Indians, stated to the writer in 1935 that he had not heard that the Indians fired the country except to clear small areas for the growing of tobacco and food crops. Kroeber (*31*) concluded that the Indians burned considerably in heavily populated areas but that the most extensive and destructive fires were set by the white man.

Effects of Fire on Soil and Water Supply

Burning the vegetation may affect soil fertility, rate of infiltration and soil erosion, and perhaps even the flow of springs and streams. These factors may be variously influenced by the intensity of the fire and by the heat created in the soil.

Chemical Influences. Burning may favorably affect soil fertility and soil moisture. The ash, although high in carbonates and poisonous to plants in excessive amounts, is rich in calcium, phosphorus, potassium, and other ingredients favorable to growth (*48*). On steep slopes much of this fluffy ash is lost by blowing or in runoff.

Probably a more potent growth stimulus than the ash is the increase in nitrate nitrogen (*1, 3, 25*) in the surface soil layer.[1] This stimulus, perhaps in combination with the ash, is seen in the production of large individual plants in the first 2 years after burning but not thereafter (Fig. 60).

Soil Temperatures. Firing of areas with a relatively small fuel supply, such as grassland or even sagebrush, seldom results in destroying much humus or a large proportion of a native perennial grass stand (*22*), but a very hot forest or chaparral fire, with abundant fuel, may

[1] Hesselman (*24*) concluded that the heat of the fire destroys the microorganisms in the surface soil layer. Later, rapid colonization of nitrogen fixing and other bacteria takes place and continues until organisms which feed chiefly upon the bacteria also come up from the deeper soil and multiply at an unusually rapid rate. Decomposition of soil microorganisms killed by the heat also temporarily increases the soil nitrogen.

destroy much of the herbaceous cover and cause temporary soil sterility (*3*).

During a fire the temperatures in the upper 2 inches of soil rise in proportion to the duration and the intensity of the flames (Fig. 61). Maximum temperatures in the surface soil layer are reached a few minutes after the fire starts and tend to destroy the microorganisms and

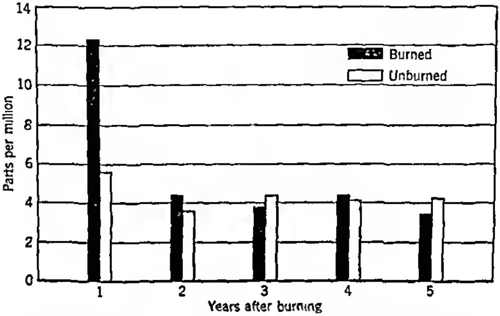


FIG. 60. Nitrate nitrogen in field samples at 0–1-inch depth, in Aiken clay loam, chamise cover. Shasta County, California. [*After Sampson (48).*]

the less fire-resistant seeds. The hottest fires occur in forest slash, mixed chaparral, chamise, sagebrush, and grassland, in the order named.

Burned soil is exposed directly to the sun and tends to warm up more rapidly than unburned lands; thus it stimulates somewhat earlier spring growth (*22*).

Infiltration and Soil Erosion. One of the most unfavorable reactions to burning is the tendency towards decreased infiltration and increased soil erosion. The most important single influence of vegetation is its stabilizing effect on the soil. On well-vegetated areas the force of rainfall is measurably minimized; hence little soil is lost. There is much evidence to support the claim (*3, 43, 47, 49, 53, 59, 68*) that burned watersheds exhibit increased overland flow and that this accelerates the silting up of areas in the path of the stream (Chapter 23). The life of water-storage reservoirs may be materially lengthened by maintaining at all times an effective vegetal cover. It should be kept in mind that temporary clearance of the brush, as by burning, is only one step in the improvement of such areas. To be worth while, clearance, by whatever means, must be followed by proper management,

including reseeding if the sites justify it, sometimes by special means of erosion control, by correct stocking rates, or by a rational season of grazing

The steeper the slope the greater the probability of severe erosion On extensive areas of California chaparral the surface soil is strewn with pebbles, giving the appearance of an "erosion pavement." Whereas this stony surface protects the soil particles underneath by absorbing

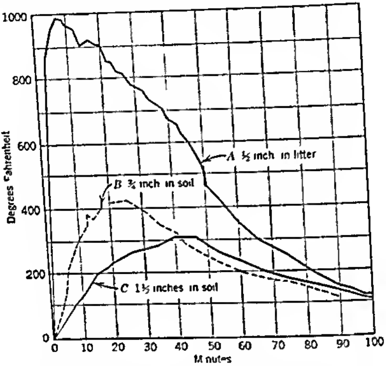


FIG. 61 Soil temperatures recorded during a chamise fire A, thermocouple ½ inch in duff, B, ¾ inch in the soil, C 1½ inches in the soil Mendocino County, California [*After Sampson* (48)]

the force of storms, it causes runoff to concentrate in rills and induces formation of gullies But gullies are more numerous on areas frequently burned Lands vegetated with chaparral generally seem to be well protected against erosion (*47*, *49*) Veihmeyer and Johnston (*61*), working on plots of California chaparral, concluded that runoff and erosion did not consistently increase after burning, however, Rowe (*47*), studying the California woodland chaparral, found that burning markedly increased runoff and erosion The diversity in these results may be accounted for by different past histories of the areas, by faulty catchment installations of the test plots by Veihmeyer and

Johnston and by differences in precipitation and soil types of the plots studied

Although it is generally recognized that watershed burning has increased runoff and erosion in many instances, no increases have been reported in some cases Many small but complete watersheds of diversified topography, soil type, rainfall, and cover (the cover to be burned or the vegetation otherwise manipulated) need to be studied However, the application to large watersheds of runoff and erosion records obtained on small plots seems questionable

Soil Moisture and Spring Flow The amount of water that infiltrates into the soil, though influenced by many factors, may be modified by fire, especially when accompanied by close grazing Changes in rate of infiltration after burning vary with slope and soil texture (*26*) A fine, close textured soil is more likely to lose its infiltration capacity when denuded than a sandy, coarse, or gravel covered soil Veihmeyer and Johnston (*61*) concluded that chaparral burning allowed the soil to become wet throughout its full depth of 42 inches just as soon as that of the unburned plots Sampson (*49*), and Veihmeyer and Johnston, reported that on chaparral burns the moisture in the upper 3 to 12 inches of soil was depleted early in the season where there was a fair cover of herbs, but at depths of 24 to 36 inches burned plots contained from a trace to 6 percent more moisture until the brush had partly regrown Burning, then, appears to conserve water in the lower soil layer by killing or temporarily reducing the top growth of deep rooted woody vegetation—unless, perhaps, steepness of the area or trampling by stock results in increased runoff The moisture thus saved could indicate that somewhat less rainfall might be required the following season to induce movement of water through the soil to streams and springs

Various stockmen (*17*) and some scientists have contended that broadcast burning of chaparral and other tall vegetation on dry sites induces renewed flow of springs and streams Biswell and associates (*4*) reported increased flow of a spring after late summer burning of a dense woodland chaparral hillside in Madera County, California, and some flow over a road after a 500 acre chaparral burn in Lake County Copeland (*41*) observed occasional damp spots after autumn chaparral burning in Butte County, California

The water of such increased flow—a matter not yet established—would have to come from a free supply stored deep in the soil or in the rock strata of dry-slope vegetation where but a few stringer roots occur, but on slopes supporting riparian (stream bank) vegetation with roots anchored in soil containing free water throughout its profile,

increased flow may be expected within a few hours after removal of the cover. On dry slopes some free water could conceivably find its way into springs and seeps by the heat waves induced by the fire and by exposure of the soil to direct insolation after removal of the vegetation. Bouyoucos (*8*), in laboratory studies, reported that a rise in soil temperature forced some water out of the soil. He attributes this to expansion of the gases and increased vapor pressure and perhaps also to decreased surface tension. Springs or streams, as stated, might be expected to flow more freely when riparian vegetation (tall stream-bank growth) is cut or destroyed by fire. Such increased flow could mistakenly be attributed to burning of dry-slope vegetation. The influence of burning or otherwise thinning of tall vegetation on water relations needs additional study. Steep slopes should be burned with caution, especially those with relatively light, highly erodable soils (*45*).

Fire, Wildlife, and Recreational Areas

Fire and Wildlife. All form of wildlife are affected by fire. Small arboreal mammals, like tree squirrels and chipmunks, are reduced in numbers for long periods by crown fires. But most small surface-dwelling mammals such as ground squirrels, gophers, and field mice, as well as reptiles, are only temporarily reduced because enough individuals escape the fire to repopulate readily (*30, 43*). Because of their mobility, large predators like the coyote, fox, and mountain lion and such ungulates as deer and elk are little affected by fires of ordinary size, but large rapidly moving fires may kill many of these mammals or they may die from starvation for lack of winter feed.

Large burns are also destructive to birds, their eggs, and their nests (*33*). But small burns with ample cover nearby enhance their food supply. In southern woodlands Stoddard (*57*) found that judicious spot burning provides quail with secluded grounds of abundant choice food.

Fish may be harmed by burning of stream-bank vegetation because it reduces insect and plant foods and disrupts the habitat. Burning of large, contributing watershed may cause the following adverse habitat changes: the stream temperature may be raised, the carbon dioxide content of the water may be increased through decomposition of killed vegetation, ash and dissolved impurities may be added, and the oxygen supply of the water may be decreased.

Fire and Recreation Areas. Tourists leave recreation grounds that are being burned and advise friends to stay away from them. During a fire, business at hotels and other tourist enterprises drops sharply

and does not reach normal proportions until after the smoky atmosphere has cleared (*54*) Often the greatest loss is the damage done to the playground proper and to roads that lead to recreation areas Such fire damage can often be avoided or minimized by burning for hazard reduction

Controlled Burning for Reduction of Hazard

Disposing of inflammable material includes burning brush, slash, snags, and other debris

There are three types of burning for this purpose (1) strip burning along roads, railroads, and other traveled ways and along fire breaks for fire prevention or pre fire suppression, (2) spot burning to remove logging slash and other hazardous concentrations of either heavy or flash dead fuels, and (3) broadcast burning over an entire area

The use of fire purely for hazard reduction has been subject to some confusion, because there are these three types and because terminology regarding them has been loosely used Also, many persons speak of "light" or "heavy" burning when referring to hazard reduction by controlled burning

Light burning implies the use of fire in early spring, late fall, or winter to reduce the danger of wild, destructive fires It is a popular practice in the longleaf pine flats of the Southeast (*63*) to improve and protect the timber and the grazing Light burning of forested areas can be practiced successfully only where the trees are resistant to fire (*9*)

Heavy burning implies firing during the dry, hot season to destroy the existing cover, facilitate travel and livestock handling, increase forage for game, and enhance hunting Heavy burning places no value on the existing vegetation *per se*

Neither term implies the degree of pre-planning or of control measures involved in the firing operation

Burning Practices in Foreign Countries

Man's use of fire to alter or suppress brush and/or timber in many instances has been essential to his well-being, but too often it has resulted in converting large areas to desert and bare rock According to Shantz (*53*)

> In regions of relatively heavy rainfall, such as the Pacific Northwest and the temperate rain forests of Central Africa and New Zealand, clearing off the forests by cutting and fire reduces them often to useless fields of bracken When once well established, bracken, which has no grazing

value, makes reforestation and even clearing for agriculture a tedious and costly process.

A third of the natural vegetation of the earth's surface has been affected by fire. In each case the vegetation is thrown back to a less luxuriant, drier, or often less productive type.

The most extensive of this unproductive growth is the Mediterranean 'hard' brush. It includes most of the brush lands bordering the Mediterranean Sea in Africa, Asia, and Europe (*53*). From Spain throughout much of the Balkan states this form of brush has been burned for hundreds of years to improve the pasturage. But, like the chaparral of California and similar brush in South Africa, Australia, and New Zealand, the more it is indiscriminately fired the less desirable is the vegetation. Over much of its distribution the shrubs are largely unpalatable. Everywhere geographers regard this cover as fire-induced, for it tends to become denser as the quality of the site is lowered as a result of repeated burning.

In New Zealand, Zotov (*68*) reported:

> Fire is the primary cause of depletion of the tussock grassland. Together with overgrazing it is responsible for the more or less complete destruction of the desirable vegetation.

In a heavy rainfall region of New Zealand, Taylor (*57*) noted:

> The chief cause of the hill country deterioration is soil erosion. The frequent use of fire to control scrub and fern growth is the greatest single factor aiding soil erosion.

Tansley and Chipp (*58*), studying New Zealand tussock lands, concluded that proper seasonal grazing should largely replace range burning.

Over extensive areas of the Union of South Africa, Bosman (*7*), Phillips (*43*), and others (*60*) favored limited or occasional burning in the dormant season to remove the coarse, dry grass. Bosman concluded: "On the whole, veld burning should be discontinued as far as possible." This observation is supported by Staples (*55*) and others (*58*).

In tropical forest, brush, and grassland—notably in Burma, India, and Brazil—bamboo, bracken, or scrub soon occupies the burns. In Burma and India, bamboo also replaces burned evergreen forest (*58*), and only the formation of Government reserved forests has saved these great natural assets.

In Brazil, Vincent (*62*) concluded that fire can cause devastation but,

when properly applied, often improves the range. Fire is often used where no benefits are derived.

To summarize, everywhere the practice of burning is challenged by some landowners, scientific groups, and individuals In some localities, grazing lands have been heavily damaged by too frequent and unseasonable burning, in other places rational burning has proved beneficial and even necessary. But many ranges are fired too frequently.

Control of Noxious Woody Growth on Range Lands of the United States

Control of undesirable woody growth on range lands in the United States is practiced chiefly in the following plant associations the chaparral of California and adjacent areas, sagebrush of the Great Basin and adjacent lands, mesquite and other scrub of the Southwest, scrub and the "rough" of the midwestern prairie, the brush and rough of the southern pine region

Control of Chaparral in California

"Chaparral"[2] is the term collectively applied in the West to the scrubby growth characterized by sclerophyll evergreen leaves, often thorny branches, and an extensive root system It occupies the intermediate or foothill areas between grassland and forest and is best developed in regions of the Lower and Upper Sonoran life zones In the United States chaparral is a western formation It grows best in *the foothills of the Rocky Mountains, the mountains of Utah*, Arizona, southern Oregon and California (*64*). It appears to be climax over much of the drier parts of its range but is apparently subclimax on the deeper soils in the heavier rainfall areas.

The discussion in this section of the chaparral is confined to the California formation, but the recommendation for suppression may be applied to chaparral lands elsewhere

The California chaparral occupies several million acres (*48*); it includes various kinds of brush covers occurring on many soil types and on different slopes and exposures (Fig 62) The dominant plants are chamise (*Adenostoma fasciculatum*), blue, live, and scrub (*Quercus*

[2] In Corsica (*53*) this plant form is called "macchia', in Spain, "chaparro" or 'tomillares", in the Balkans, 'phrygana', in South Africa, "fijnbos," "garigue," or 'heath", by the Basques in the Pyrenees, 'chabarro , and in south Australia, "mallee" or "mulgabrush" Throughout the world chaparral is regarded as fire thriving, for after burning great numbers of crown sprouts and seedlings usually come in

spp) manzanitas (*Arctostaphylos* spp), ceanoth (*Ceanothus* spp), and buckthorns (*Rhamnus* spp) There are both sprouting and non-sprouting species the sprouting being more difficult to control Chamise mixed chaparral, live oak and blue oak form a large part of the brush acreage

FIG. 62 Typical California chaparral area ranging from pure chamise on the bleaker steep slopes to mixtures of ceanothus live oak, manzanita and chamise on the different sites The soil is shallow and mostly of low productivity A large proportion of the chaparral lands is primarily useful for production of game animals and should be managed for that purpose Shasta County

Although the chaparral lands are most useful for watershed protection and the production of a maximum supply of usable water, they are also important for livestock grazing, game production and as hunting grounds The more fertile areas have been cleared for homesites and farming A small acreage is used as campsites, and some of the streams attract the fishermen. In many localities the treatment of these lands is of concern to the people as a whole

Stockmen burn these brush lands to improve the pasturage and to facilitate handling the stock Most sportsmen favor periodic burning to increase the feed for game—especially deer and quail—and to facilitate hunting

Although more research on this problem is needed, answers to some frequent questions concerning the control and administration of the chaparral are given below

1. *Do all chaparral areas respond equally well to fire?* No. Properly managed flats or gentle slopes with fairly deep soils may produce abundant, nutritious forage after burning. But the large acreage of thin soil—especially the steeper slopes—produce little forage when fired. Burning of low-growing stands of chamise on severe sites yields little forage. But burning robust mixed stands of chamise, manzanita, and ceanothus on deep, productive soils results in a fair forage crop for 2 to 4 years after burning (*48, 51*). Nonsprouting brush fields usually produce more forage than areas of sprouting brush.

Many long-protected brush fields are so dense that livestock cannot work into them, and the understory vegetation is sparse. That is why stockmen desire to burn these areas even though the resulting pasturage is temporary and generally poor (*50, 65*).

2. *How can brush best be controlled or removed?* By burning, toxic sprays, mechanical means, and biological control.

Burning is the most common method. But it should be recognized that a second or even a third fire at intervals of 2 to 4 years may be required to clean up the woody remains of the initial burn and to kill the brush seedlings. Reseeding with annual grasses may be required to provide fuel for the reburn. (*4*). According to Sampson (*48*)

> Where burning at intervals of 2 to 3 years is possible, stands of sprouting chaparral tend to give way more or less to grass and weeds. But burned areas seldom produce enough herbaceous growth to assure the running of sufficiently hot fires to consume the brush seedlings, the sprouts, and the charred, dead stems . . . The availability of pasturage elsewhere will determine whether the forage produced after the first fire should be sacrificed solely for improvement purposes.
>
> In late summer or early autumn of the second or third year following the first fire, the stems may be leveled to the ground by dragging a log over the area with a tractor. After the dragging the area is reburned.

Although reburning to favor invasions of grass has given some good results, its general effectiveness has not been fully demonstrated (*51*).

Toxic chemicals are still too expensive and too uncertain of results to be used extensively on chaparral. Such growth-regulating compounds as 2,4-D (2,4-dichlorophenoxyacetic acid)[a] and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) have been tested; also such nonselective herbicides as ammate (ammonium sulfamate), arsenicals (especially

[a] The most common forms of 2,4-D are the acid and the salts and esters of this acid. The acid may be mixed with sodium carbonate or bicarbonate. The resulting powder will mix directly with water (the acid itself will not). The esters commonly used are the methyl, ethyl, isopropyl, and butyl. The 2,4-D acid and its compounds are neither explosive, inflammable, poisonous, nor corrosive (*21, 67*).

sodium arsenite), fortified petroleum products (particularly of kerosene and diesel oil), and TCA (trichloracetates) (*38*) Spraying the seedlings of certain chaparral species with 2,4-D or with ammate has shown some promise (*4*)

Permanent and complete removal of the chaparral may best be done with a bulldozer, or by lopping chopping, and girdling Only the more productive, relatively level lands justify the expense of about $15 00 per acre

FIG. 63 Angora goats on a woodland-grass area burned 5 years previously The open-grass portion formerly had a scattered to-dense stand of live oak, ceanothus and wild rose Amador County, California

Biological clearing as with goats, is effective on girdled chopped, and newly burned areas if the sprouts are palatable (Fig 63) Stocking is often desirable at the rate of 1½ goats per acre for the first 2 years and at a lighter rate thereafter A heavy deer population will destroy brush sprouts and seedlings on burns of about 5 acres if the burns are spaced no closer than a mile or so apart (*46, 48*)

3 *Is artificial reseeding of chaparral burns successful?* Usually, no Best results have been obtained by seeding with annual ryegrass (*Lolium multiflorum*), cereal rye and certain native or naturalized annuals (Chapter 11) The primary objectives of reseeding are to set up competition with the brush seedlings, provide fuel for a reburn, and protect

the soil against erosion. The secondary objective is to improve the grazing.

Most perennial grasses and legumes are generally unsuitable, since they become established slowly and are mostly crowded out by invading plants. Such perennials as Harding grass, smilo, and tall meadow oatgrass have shown some promise on the better sites where some native perennial grasses occur. Biswell and associates (*4*) concluded that reseeding is justified only on units where the grass had been crowded out by dense brush before burning and on spots where the fire destroyed the grass seed. Although hand seeding of these spots conserves seed, sowing of large areas with an airplane is not overly expensive and may offset local wastage of seed.

On the better, mechanically cleared sites, domesticated perennial grasses and legumes may be established, temporarily at least, though at considerable expense (*35*).

4. *Do stockmen prefer to keep their rough lands in brush, burning them periodically to induce sprouting for feed?* Cattle growers favor clearing the brush, whereas many sheep and goat raisers, whose animals utilize the sprouts far better than cattle, prefer an open brush stand. Stockmen who must rely on brush lands for much of their pasturage may well resort to a program of *rotation burning* to provide some feed each year (*48*). The brush field may be divided into 3 units so the burning can be done at 3-year intervals or on a 9-year rotation basis. The animals should not be kept on the chaparral burn throughout the summer and fall, because of the low nutrition of the feed after the spring period. A few acres of irrigated pasture or mountain range for summer grazing is a distinct asset.

5. *What is the cost of controlling California chaparral by burning?* Controlled burning in California, as in most other states,[4] is administered by the State Division of Forestry, which encourages stockmen to take out fire permits, construct needed firebreaks, and have adequate help on hand during burning. The Forestry Division provides standby crews at state expense. Cost per acre varies chiefly according to size of area, risk involved, character and density of the brush, slope and exposure, and weather. The relation of cost to size of burn, from unpublished data of the author, is indicated in Table 16.

The figures in Table 16 include only "reported" expenditures and

[4] Penalties for damage resulting from unpermitted burning or for carelessness with permitted fires can be severe. Losses of winter feed, timber, watershed values, and cultural features resulting from escape of prescribed fires are frequent and often expensive.

not such items as (1) additional costs of renting land, purchasing feed, fencing, riding and maintaining the range, including periodic reburning and reseeding, and (2) loss of soil fertility, runoff, erosion, downstream silting and possibly flood damage. The reports indicate that the ranchers' cash expenditures are lowest on the steepest slopes, which, incidentally, are the least productive and least desirable for management through brush control.

TABLE 16

COST OF BURNING

Size of Burn (Acres)	*Permittee Cost* (per Acre)	*State Cost* (per Acre)	*Total Cost* (per Acre)
40	$3.00	$0.70	$3.70
80	2.60	0.60	3.20
120	2.20	0.50	2.70
160	1.80	0.35	2.15
200	1.30	0.30	1.60
240	1.00	0.25	1.25
280	0.80	0.20	1.00
320	0.60	0.20	0.80
360	0.60	0.20	0.80
400	0.60	0.20	0.80
440	0.60	0.20	0.80
480	0.60	0.20	0.80
520	0.60	0.25	0.85
560	0.60	0.25	0.85
600	0.60	0.30	0.90
640	0.60	0.35	0.95

An analysis of 190 State Forestry Division cost reports of permitted burning during the 1947 and 1948 seasons[5] indicates that on burns larger than 640 acres (not shown in Table 16), the cost to both the permittee and the State decreased. For example, on burns of about 1500 acres the cost to the permittee was about 45 cents, to the state 18 cents. Such acreage may prove to be approximately the upper limit in the economy of burning.

The claim that burning by permit has reduced the acreage of fire escape is not substantiated by the records for the years 1946–1950, as shown in Table 17.

6. *Why the controversy over chaparral burning?* Chiefly because of the diversity of interests in the land resources. The argument is concentrated among four groups: (1) stockmen who burn the chaparral lands periodically, causing financial losses if any of these fires escape to

[5] Results taken from a report on a cooperative project on cost and returns of brush burning between the California State Division of Forestry and the author.

adjoining lands; (2) sportsmen who like the brush fields opened up by firing to facilitate hunting and to increase the game food supply; (3) administrators of watersheds who feel that the plant mantle must be protected from fire to obtain a continuous, maximum yield of usable water; and (4) foresters, timber owners, and those invested in recreation areas, whose lands adjoin chaparral fields, and who find it difficult to protect their properties from escaped fires.

TABLE 17

PERCENTAGE OF ESCAPE BURNS, 1946–1950

Year	*Controlled Burns* (*Under Permit*) (Acres)	*Escape Burns* (Acres)	*Escape Burns* (Percent)
1946	64,296	9,399	12.7
1947	35,807	6,137	14.6
1948	24,041	6,058	20.1
1949	83,055	14,358	14.7
1950	86,434	16,030	15.6

The indiscriminate burning of inferior chaparral lands accounts for much of the adverse opinion concerning the value of firing. Much of the rugged outlying area is relatively inaccessible to livestock and undoubtedly most suitable for game production and hunting.

7. *What are the policies concerning control of the California chaparral?* They are indefinite. The fire laws and policies now administered by the State Division of Forestry are likely to persist. The fire permit will be passively acceptable to the stockmen so long as it virtually vindicates them (by showing good intentions) from suit against property damage and gives them free advice on how to burn with reasonable safety. Various stockmen pressure groups may eventually succeed in securing legislation to subsidize all cost of chaparral ranch burning. This might be done by reimbursing the stockman for his expenditures or by vesting in the State Division of Forestry the responsibility of carrying out the entire brush suppression program. Possibly a step in that direction was made in 1949 with "an appropriation of $35,000 to provide and equip two crews for standby service on control burns." The extent to which the state can justify providing standby crews to benefit individual land owners needs clarification. Is it the aim of the state legislators (1) to assist stockmen in their burning, or (2) merely to reduce the chances of fire escape? Where is help of this kind to end? It has been shown that burning often increases runoff, erosion, and floods. A handful of stockmen are now receiving state help on a substantially increasing acreage each

year (83 000 acres under permit in 1950) at the cost of reduced reservoir storage capacity the preservation of which is of fundamental importance to the large numbers of people in the valleys below The state crews do not now conduct the actual burning, and stockmen occasionally question why they don t Even now the taxpayer is meeting a considerable part of the brush control and reseeding costs through state activities and benefit payments of the Production Marketing Administration (P M A) The State Division of Forestry, essentially through pressure by powerful stockmen s organizations is proceeding with an action program in brush burning in advance of mature research guidance of the ultimate effects of repeated firing of the land or the economic feasibility of the program

When wild lands are classified as to their most permanent economic uses—a study under way in California—there may be less burning of the steeper brushy slopes and other unproductive areas The education of stockmen and others to recognize that many brush areas are clearly marginal for livestock grazing and are best suited for game production should be most helpful If local watershed values are not endangered a program of prescribed rotational burning may be adopted to enhance the vast low producing acres for deer and other game Burning for hazard reduction and removal of the chaparral by mechanical means on good sites is destined to increase

Control of Big Sagebrush in the Great Basin Region and Adjacent Lands

Big or black sagebrush (*Artemisia tridentata*), and its varieties is a nonsprouting deep rooted many branched shrub, 2 to 6 feet high with small aromatic gray leaves 3 cleft at the tip It is one of the most widely distributed western shrubs and is especially characteristic of the Great Basin region (*16*) Luxurious stands frequently occupy productive soils of near neutral reaction In the winter big sagebrush furnishes some browse for livestock and game

Big sagebrush has invaded a large acreage that formerly supported perennial forage grasses (Fig 64), and the more productive of these areas justify its removal Burning is the chief means of suppression but railing plowing flooding or mowing are occasionally employed usually followed by reseeding

Answers to common questions concerning the control of big sagebrush follow

1 *Why not replace big sagebrush with grass by deferred rotation grazing and conservative range use?* On areas where the sagebrush is not overly dense and ample seed plants of the better forage grasses

remain, the deferred-rotation grazing practice is generally effective. But where the sagebrush forms a dense cover, improved management favors the grass but little and the sagebrush should be removed (*20*, *37*, *42*).

Burning is the cheapest way to destroy big sagebrush where soil erosion is not serious, but mechanical methods should not be over-

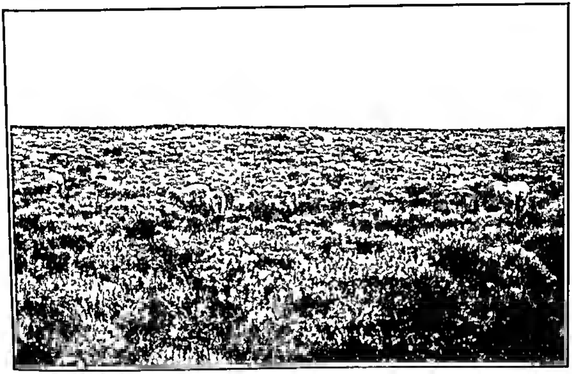


Fig. 64. Heavy invasion of big sagebrush on formerly productive perennial grassland in Idaho. The brush may be controlled by burning, railing, or plowing, followed by reseeding, preferably to crested wheatgrass, smooth brome, or a combination of these with the better native perennial grasses.

looked. Burning sites of shallow soils or steep slopes should be avoided. Including building of the necessary fire lines, burning costs have averaged about 20 cents an acre and seeding about $2.00 per acre, so burning pays only on productive lands. Inferior-appearing stands of big sagebrush—averaging about 2½ feet tall—indicate poor soils; strong-appearing dense stands—averaging 3½ to 5 feet tall—are indicative of good soils. On various superior sites in Utah, Idaho, and Colorado the forage has been more than doubled under conservative grazing after burning (*37*, *42*).

2. *What management plans are especially recommended for control of big sagebrush?* The firing should be done in late summer or autumn after the seeds of the grasses have scattered. Stock should be excluded the first year after burning to protect the grass seedlings, and grazing should be light the second year. Undue trailing of stock over the area

should be avoided at all times The manager should make sure that the fire can be controlled that the grass will be favored, that soil erosion will not be severe, and that conservative grazing will be practiced afterward Where few good grass seed plants remain, the area should be reseeded with crested wheatgrass, smooth brome, or slender wheatgrass

Control of Woody Growth in the Southwest and Southern Great Plains

The states of Arizona, New Mexico, Texas, and Oklahoma primarily comprise this area The more troublesome grassland invaders in the arid portions—Arizona, New Mexico, and western Texas—are acacias (*Acacia* spp), cacti (*Opuntia* spp), juniper (*Juniperus* spp), lote (*Condalia obtusifolia*), mesquite (*Prosopis juliflora* var. *glandulosa*), oaks (*Quercus* spp), and whitebrush (*Aloysia ligustrina*) In the southern Great Plains, sand sagebrush (*Artemisia filifolia*) is the most widespread, but oaks, plums (*Prunus* spp), and cacti also need control

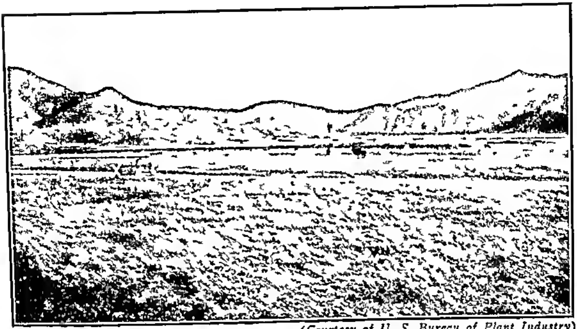
The tremendous importance of suppressing the millions of acres of brush in this region is being studied by federal and state agencies Foremost in abundance, distribution, and curtailment of grass growth is mesquite which, often with other shrubs, occupies some 60 million acres (*36*) Burning, mechanical removal, herbicides, and biological control are employed on some species, or a combination of some of these methods may be used

1 *Is mesquite of any value on the range?* The 4- to 8-inch seed pods are palatable to livestock and game animals, and the young twigs and leaves are browsed lightly The mesquite is used for fence posts and fuel, also the plant protects the soil from erosion Overbalancing these advantages, however, are these facts (1) the seeds germinate readily after having passed through the animal, and (2) the extensive root system robs the grass of moisture and the top growth shades out the grass (*29*) Control, rather than complete elimination of the shrub, is preferred (*39, 40*)

2 *Can mesquite be eliminated or effectively controlled by burning?* No, partly because of its parklike stand, and because burning, or chopping, is followed by vigorous sprouting After a fire many seedlings come in Allred (2) points out that the vigorous sprouts after burning soon recapture the site

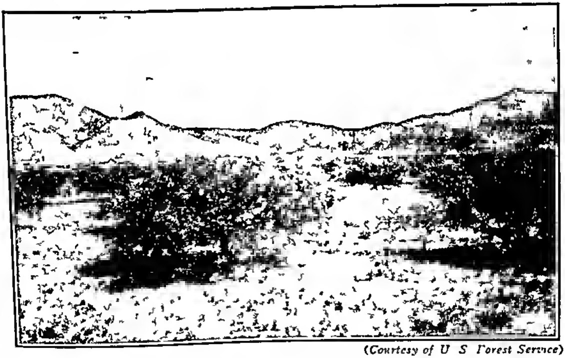
3 *Will a strong grass cover curtail invasions of mesquite?* Areas well stocked with perennial grasses are nearly free from mesquite (Figs 65 and 66) Conservative range use and deferred-rotation grazing are important in minimizing mesquite invasions

4 *Can mesquite be removed effectively by mechanical means?*



(Courtesy of U S Bureau of Plant Industry)

Fig 65 Open grassland in southern Arizona, photographed in 1903 Initial infestation of mesquite on the left is indicated by a cross



(Courtesy of U S Forest Service)

Fig 66 Mesquite infestation, evidently due to overgrazing and scattering of the seed by domestic livestock Photographed in 1941 from same location as that of Fig 65

Mechanical removal is effective if done correctly The whole plant must be dug out deep enough to unearth the dormant buds 4 to 12 inches below the ground level Removal by hand grubbing is the cheapest on small areas of chamise or most other brushes

On larger areas, power grubbing machinery has been used with varying success Heavy machine grubbers sever the roots 6 to 12 inches below the ground surface Unfortunately, much of the perennial grass stand is killed, and many small mesquite bushes are left These, together with the numerous incoming brush seedlings, soon revive the brush cover (*19*) Bulldozing of mesquite is not satisfactory (*66*) Of the various other implements built to eradicate brush may be mentioned the brush cutters, mowers, root ploughs, power saws, stinger blades and cable equipment Any equipment, like saws and mowers, that merely removes the top growth stimulates a rapid regrowth of the mesquite Cabling out large, stiff mesquite plants is done by running two crawler type tractors parallel to each other about 100 feet apart and dragging a steel cable between them This method of removing rigid mesquite and other large plants is relatively inexpensive and effective

Controlling mesquite and other brush by heavy machinery needs more study

5 *Can chemical means be used to remove mesquite and other brush?* Spraying with suitable herbicides or applying an oil around the plant's crown has been fairly successful

Kerosene, diesel, and crank case oils will kill mesquite and other brush species if enough is applied at the base to penetrate through the bark and destroy the deepest buds A basin should be dug close to the plant and the oil then poured from a spouted can around the lower few inches of the trunk The soil should be dry If it is porous, it should not be dug Fisher (*19*) reported excellent results with mesquite on porous soils by first cabling the area, then following up in a few months with an oil treatment of the sprouts and seedlings

Sodium arsenite or arsenic pentoxide has proved the most reliable and effective brush killer of the chemicals tested on mesquite and many other woody plants (*39, 41, 67*) The poison may be injected into the shrub's bole, or the trunk may be frilled (chopping a shallow cup near the base of the trunk) or girdled and then treated with the arsenic solution, or a weak solution may be poured around the base of the plant Allred (2) and Parker (*39*) caution emphatically on the care when arsenite is used, because of its extreme toxicity to man and animals

Ammate (ammonium sulfamate), when applied properly, is fairly effective on some sprouting trees and shrub species and is not poisonous

to stock Dense, many stemmed shrubs should be sprayed about the time the leaves have attained full growth Four pounds of ammate crystals dissolved in 1 gallon of water is recommended In 1950 treating of dense sprouts of various species 1 to 3 feet high amounted to $15 to $20 per acre excluding labor (*19*) To kill large trees, small cups 2 to 4 inches apart are chipped out around the trunk and a tablespoonful of ammate crystals inserted in each cup Treatment should be made in summer or fall Use of ammate on mesquite has not been successful

The use of 2,4 D and its derivatives on woody growth in this region is still largely in the experimental stage Savage, Brown, and McIlvain (*52*), working at Woodward, Oklahoma, report satisfactory results in spraying sand sagebrush and certain larger shrubs with 2 4-D from an airplane Mowing sand sage in June destroys much of the sage stand and measurably increases the grass cover, but the place of 2,4-D and 2,4,5-T in brush control generally is in the experimental stage

REMOVAL OF THE 'ROUGH ON THE MIDWESTERN TALL GRASS PRAIRIE

The tall grass prairie, dominated by bluestem grasses (*Andropogon* spp), has long been subject to annual burning in Kansas Oklahoma, and parts of Texas Firing is done chiefly to remove the dead grass (called the 'rough) remaining from the previous year, to promote early spring growth and to control weeds and brush Differences of opinion exist among stockmen and others concerning the use of fire and the proper season to burn

The earlier burning practices of the midwestern white man seemed to have been patterned after those of the Indians, who are credited by some workers with keeping the tall grass prairie treeless by frequent firing Droughts, however, seem to have been the chief influence in keeping out the trees (*13*) According to Cox (*15*) The most adverse weather cycle or the most severe drought occurring over a long period of time in any region determines the character of the vegetation in that region '

Answers to the following common questions lean heavily on the work of Aldous (*1*) and Hensel (*22*)

1 *Why remove the dead grass of the previous grazing season?* If not removed the old grass will adversely shade the current forage crop and hinder grazing In especially good growth years additional numbers of stock might be pastured thereby getting the benefit of the forage that would otherwise be burned On level areas the excess forage can be conserved by mowing and stacking it for use later

2 *When should the burning be done?* In the spring when the soil

is moist. Burning when the ground is dry, as in the autumn, is likely to cause serious damage to soil and vegetation.

3. *How does burning affect composition and yield of the tall prairie?* Aldous (*1*) found spring growth slightly heavier and earlier due to greater insolation of the soil. By midsummer the yield was about the same on the burned and unburned plots, but by autumn the unburned area had a slightly heavier grass cover. The yield was least on plots burned in the fall.

4. *Should snowberry and sumac be controlled by burning?* Snowberry (*Symphoricarpus* spp.)—called buckbrush in the Midwest—and sumac (*Rhus* spp.) are common weedy shrubs in the tall grass prairie region. Burning or cutting the snowberry in late spring, when carbohydrate stores are low, kills many of these plants, but sumac is not killed unless burned or cut in June, a date too late for effective pasture burning.

Burning of the "rough" induces more uniform and unhindered grazing. But sparsely vegetated south and west slopes should not be burned because of needed protection of the soil.

Infestations of sumac can be controlled effectively by airplane spraying with 2,4-D.

Burning of Other Grasslands

Short Grass-Mid Grass Prairie. Although pasture burning is not practiced regularly in the zone between the tall prairie and the short-grass region, many fires occur accidentally.

Hopkins and associates (27) at Hays, Kansas, found that buffalo grass (*Buchloe dactyloides*) areas burned in April produced little growth in May, whereas on a burn of the previous fall growth started early and made a fair height. The fall-burned pasture, however, showed a 25 percent weight loss of buffalo grass and 50 percent of blue grama (*Bouteloua gracilis*). Much of the little bluestem (*Andropogon scoparius*) and other mid grasses were killed by the fire.

California Annual Grassland. On this cover the author has noted that burning lowered forage yield and raised the number of forbs for some three seasons. Hervey (23) concluded that fire has no place on these grasslands because (1) grasses decreased and forbs increased in abundance, (2) spring growth on burned areas was delayed, the height growth being less and the grazing capacity lowered, and (3) such forbs as bur clover and filaree increased the first year.

Downy Chess Infestations. Downy chess (*Bromus tectorum*)—also called cheatgrass—is locally abundant in the Rocky Mountains, Great Basin, and Great Plains. Early in the summer the heavier stands

cause a serious fire menace. Grazing when the stand is green provides satisfactory forage and protection against fire and curtails reproduction (*20*, *28*). Burning just before seed maturity has been partly successful. Creating fire breaks by burning oiled strips of the green grass has also proved useful (*34*).

Stubble Burning. Burning of stubble to dispose of the "rough" after harvest is common practice in low-rainfall regions where straw decays slowly. Here are some of the "don'ts" to watch out for (*56*): don't burn the stubble in the fall, for it holds the snow and aids in the control of soil blowing; don't burn on soils that have started to blow; don't burn in dry years when the stubble is short or the stand poor. Burning, however, makes for a clean seedbed upon which wild oat or seeded rye readily becomes established.

Control of Understory in the Southern Pine Region

In the longleaf, slash, and loblolly pine forests of the southeastern states, timber production is the primary industry. Much of this region has been cut over and burned and is now occupied by thrifty second growth interspersed with open grass and brushland. Cattle production is extensive and expanding. Fire has long been used on the level lands to keep the understory open. In many localities prescribed burning favors both forest and range (*5*, *6*, *63*).

Three associations occupy most of the southern forest. Loblolly pine (*Pinus taeda*) and hardwoods cover the upper or northernmost Coastal Plain; longleaf pine (*P. palustris*) and slash pine (*P. caribaea*) the middle Coastal Plain; longleaf pine, slash pine, and bald cypress (*Taxodium distichum*) the lower or southernmost Coastal Plain. Along the streams are usually strips of mixed bottom-land hardwoods (Chapter 15).

1. *Was the longleaf pine forest extensive and open before the coming of the white man?* Evidently it was (*63*). For the past century stockmen have burned the forest at any season (*18*). This promiscuous burning has been destructive and is still too common; however, longleaf pine seedlings older than 1 year are remarkably resistant to fire. Chapman (*12*) proposes burning the longleaf pine understory before seedfall; this to be followed by fire suppression until the seedlings are about 3 years old and still in the "grass" (heavy needle) stage; then burning again.

2. *Does burning favor animal nutrition by stimulating invasions of desirable forage plants?* It does. More grass and legumes are produced on winter-burned than on unburned lands. Annual lespedeza (*Lespedeza striata*) and other palatable forbs invade the better burned

sites whereas many desirable grasses are smothered out on the unburned forest

3 *How about the argument over burning these lands?* The controversy has declined. Before recognition of the fire resistant characteristics of the conifers burning the understory cover met strong objections. Many timber owners and cattlemen now practice prescribed winter burning as protection against damaging wild fires.

4 *Are management plans likely to provide for light burning of the forest?* Yes but at different time intervals according to the timber species. Lack of control over unseasonable fires is the outstanding obstacle to the progress of forestry and grazing in much of this region.

Properly stocked longleaf pine areas may be rotationally burned at intervals of about 3 years, one third of the tract being fired each year. This practice provides fresh pasturage and protects the forest from destructive fires. But frequent burning of longleaf-slash pine stands is poor practice because it will eliminate the more valuable slash pine. Firing such areas at intervals of 8 to 10 years, when the reproduction is 10 to 12 feet tall, favors slash pine (*32*).

5 *Is prescribed burning a cure all on southeastern forest ranges?* No. Too frequent prescribed burning can be seriously harmful to both timber and forage. Winter burning at proper intervals against a steady moderate wind when soil and vegetation are moist has proved most successful. The southern forests are producing only about one half of their capacity, largely because of uncontrolled fires.

6 *Is it practicable in this region to kill low-value trees by chemical means?* Yes. Control of weed trees is as big a problem in the forested South as brush control on much of the western range. Scrub oaks and other undesirable trees compete with timber and forage growth from eastern Texas and Oklahoma to Virginia.

Campbell and Peevy (*10*) found that ammate is considerably more effective than the various other chemicals tested and should preferably be applied in winter. For trees under 12 inches in diameter, where the minimum of basal sprouts is desired, concentrated ammate or crystals should be applied in cups or notches chopped low on the trunk; for trees over 12 inches in diameter, where moderate sprouting is permissible, the chemical should be applied in frills at convenient chopping height, or the undesirable large trees can be cut and concentrated ammate or crystals applied to outer sapwood of stump top. For destruction of brush, small trees, and sprouts the foliage should be sprayed.

Although frilling is the cheapest method, it does favor production of quite a few sprouts The cup and ammate crystal method is the most expensive but results in the least sprouting

Sodium arsenite, 2,4-D, and diesel fuel are unsatisfactory because of the origin of many basal sprouts

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Chapter 14

MANAGEMENT CONSIDERATIONS COMMON TO RANGES AND RANGE LIVESTOCK

Range-livestock productinn is a continuous business. Its financial returns compare favorably with those of other land uses, provided both the range and the animals are properly handled. Proper range use includes not only the harvesting of the forage crops but also maintenance and protection of important resources, notably timber, watershed, game, and recreation. Such multiple land use requires consideration of all useful products of the area and careful planning to insure maximum continuous returns from all its resources.

In this chapter we consider approved or broadly recognized rangeland practices to insure sustained forage returns. In some areas most of the points discussed should be applied; in others only a few need be instituted. Administrators and stockmen everywhere should be familiar with those broader principles and practices that are necessary to prevent waste of forage, overutilization, and ultimately lower returns from the animals.

Selection of Livestock According to Range Characteristics

To nbtain efficient use of the range, the kind of stock must be selected that is best suited to the area. Range lands differ greatly in the character of the forage and in many other ways. They also differ in the extent to which they need protection of their resources other than forage.

The factors that chiefly determine the kind of stock for which a range is best suited are: character of forage, common-use range, topographical features, presence of noxious animals and plants, distribution of water, and certain local economic factors.

Character of Forage

Grass ranges are better utilized by cattle and horses than by sheep and goats. Horses even more than cattle prefer grasses and grasslike

be more completely utilized when stocked with both cattle and sheep But if a range can be reasonably well utilized by one kind of stock there is no object in grazing two or more kinds in common (*24*), particularly when plants relished by both kinds of animals might be cropped too closely Common use grazing is useful where the number of each kind of stock is adjusted to the acreage and yielding power of the different types of vegetation It should achieve more complete grazing of the forage as a whole without overgrazing of any major plant community

Dual-use grazing is useful on sheep range where moist meadows supporting grasses and sedges would be largely wasted unless proper numbers of cattle were admitted It is also economical on sheep range where cattle unavoidably drift onto the area In such instances, the rate of stocking by sheep must be reduced to conform with the estimated drift of cattle (*4*)

Topography

Livestock differ in their capacity and inclination to utilize forage in rough country Cattle prefer level or rolling range, but altitude is of minor importance Although cattle usually overutilize forage on the flats and underutilize it on the hillsides, fairly satisfactory grazing can be obtained by developing water and placing salting grounds in localities that will induce the cattle to work over moderately steep areas Some fencing and herding are usually necessary regardless of the other measures carried out

Horses raised in rough country make good use of rough range and will travel many miles over steep areas to obtain choice forage Horses reared on level lands, however, do not adapt themselves readily to steep range and are content to feed chiefly on the flats

Sheep and goats use rougher and steeper country to much better advantage than cattle The smaller, lighter bodied breeds of sheep are especially well adapted to work over steep, irregular areas, indeed, the limiting factor in grazing such areas is the ability of the herder to handle his band Range that would be little used by cattle may, under proper guidance of the herder, be grazed to full capacity by sheep Choice midsummer conditions for sheep grazing are the cool, rugged mountain ranges of succulent herbage and browse, some of which lie above the commercial timber belt

Noxious Animals and Plants

The abundance on some ranges of troublesome animals and plants often influences the selection of stock to be grazed

plants to other forage. Even coarse, dry grass is eaten by horses with good results and with greater relish than by cattle. Sheep also eat large amounts of grass—in fact, excellent lambs are reared on well-drained succulent grass range, but after herbage maturity sheep will usually take only the seed heads of favored grasses. Goats eat little grass but will not starve where tender green grass is available. Cattle (and to a lesser extent horses) also eat various forbs, but more selectively so than sheep or goats (7, *24*, *30*, *31*, *37*, *41*). Sheep will invariably crop the palatable forbs closely before subsisting essentially on grass. Shrubs are preferred by sheep and goats more than by cattle, but several shrub species are browsed by cattle and a few are taken by horses (Chapter 10). Cattle and horses will seldom browse the shrub species closely where abundant, palatable grass is available. A combination of browse and forb range is most fully utilized by sheep, whereas predominantly browse areas are best utilized by goats. The most desirable brush range is one that is sufficiently open so that the animals can move about freely to select the preferred herbage of grasses and forbs. Both sheep and goats, in due time, will work their way through rather dense brush, provided it is palatable and the soil is not wet.

Ranges with a large proportion of meadow and open grassland, and preferably with some shade trees present, are more suitable for cattle and horses than for sheep. The latter scrupulously avoid wet meadows regardless of how fond they are of the forage available. Sheep and goats especially like well drained ranges with abundant browse and forbs, but much forage on well drained meadows is destroyed through excessive trampling by sheep in their search for preferred vegetation. Patches of tall vegetation to furnish shade are desirable for the daily "shading up" of sheep and goats (*3*, 7, *37*). These animals find their way about readily and utilize best timbered areas containing "windfalls" or those with patches of dense thickets. But even expert herding will not prevent losses caused by small numbers of sheep or goats straying away from the hand and getting lost.

Some ranges, with cover combination of grass, forbs, and browse, are almost equally suited to cattle and sheep. In such instances the question often arises as to whether one should not graze the area with both.

Common Use Range

A common or dual use range contains a forage combination—grass, forbs, browse—that allows two or more kinds of stock to graze the area to advantage at the same time through the entire season, or separately during a part of the season. Ranges with grass and browse will

be more completely utilized when stocked with both cattle and sheep. But if a range can be reasonably well utilized by one kind of stock there is no object in grazing two or more kinds in common (*24*), particularly when plants relished by both kinds of animals might be cropped too closely. Common-use grazing is useful where the number of each kind of stock is adjusted to the acreage and yielding power of the different types of vegetation. It should achieve more complete grazing of the forage as a whole without overgrazing of any major plant community.

Dual-use grazing is useful on sheep range where moist meadows supporting grasses and sedges would be largely wasted unless proper numbers of cattle were admitted. It is also economical on sheep range where cattle unavoidably drift onto the area. In such instances, the rate of stocking by sheep must be reduced to conform with the estimated drift of cattle (*4*).

Topography

Livestock differ in their capacity and inclination to utilize forage in rough country. Cattle prefer level or rolling range, but altitude is of minor importance. Although cattle usually overutilize forage on the flats and underutilize it on the hillsides, fairly satisfactory grazing can be obtained by developing water and placing salting grounds in localities that will induce the cattle to work over moderately steep areas. Some fencing and herding are usually necessary regardless of the other measures carried out.

Horses raised in rough country make good use of rough range and will travel many miles over steep areas to obtain choice forage. Horses reared on level lands, however, do not adapt themselves readily to steep range and are content to feed chiefly on the flats.

Sheep and goats use rougher and steeper country to much better advantage than cattle. The smaller, lighter-bodied breeds of sheep are especially well adapted to work over steep, irregular areas; indeed, the limiting factor in grazing such areas is the ability of the herder to handle his band. Range that would be little used by cattle may, under proper guidance of the herder, be grazed to full capacity by sheep. Choice midsummer conditions for sheep grazing are the cool, rugged mountain ranges of succulent herbage and browse, some of which lie above the commercial timber belt.

Noxious Animals and Plants

The abundance on some ranges of troublesome animals and plants often influences the selection of stock to be grazed.

Bloodsucking insects—warble or other flies, gnats, mosquitoes, and the like—are sometimes so disturbing to cattle and horses for a few weeks in the summer that it becomes impracticable to place these animals on otherwise suitable ranges. Unless controlled by DDT sprays, these pests, particularly at high elevation, may molest cattle and horses severely enough to force them to spend most of the day under cover for protection. This results in overgrazing of the congested areas and poor condition of the stock. In some instances cattle and horses are kept off the range until the fly season has passed, but such delay usually results in failure to use the forage at the peak of its nutrition. Since sheep, with their heavy covering of wool, are far better protected from these insects than cattle and horses, they should ordinarily be selected to graze such infested ranges. A herder is on hand to treat insect-infested sheep, and losses from infection of insect-induced wounds can be kept low.

Ranges that harbor numerous bobcats and coyotes, on the other hand, may best be grazed by cattle and horses. These predators may take a heavy toll of lambs and stray sheep and cut deeply into profits; their damage to cattle, calves, horses, and colts is usually negligible. Areas troubled seriously by these predators are now given special attention on the western range by Federal and state hunters and trappers. This control program has resulted in minimizing sheep losses measurably on some areas.

Among the noxious plants, poisonous ones must be given closest attention, but mechanically injurious species should not be overlooked. Curiously, a plant poisonous to one kind of animal may not necessarily be so to another species; moreover, some toxic plants are almost wholly unpalatable to some animals (*32, 33*). On the western range larkspur (*Delphinium* spp.), for example, annually causes heavy losses to cattle, whereas sheep graze it without distress; deathcamas (*Zigadenus* spp.) inflicts heavy death losses among sheep but almost none among cattle because they eat little of it; St. Johnswort (*Hypericum perforatum*) frequently causes illness among sheep, but cattle are seldom troubled because they seldom take it. The presence of certain species of poisonous plants may occasionally determine the class of stock to be grazed, especially in the high mountains.

Among the mechanically injurious plants foxtail barley (*Hordeum jubatum*), because of its awns, causes much distress at maturity, especially among sheep. A wise practice, where infestations are heavy, is to graze sheep before the awns appear and after the seed heads are cast. Another practice is to graze foxtail barley areas with cattle, since they are less troubled by the awns than sheep.

Distribution of Water

The kind of animal that should be selected to graze upon a given range may occasionally be determined more by the amount and distribution of the water than by the character of the forage and certain other local factors. If the watering places are too far apart, a considerable acreage adjacent to the drinking places will become seriously overgrazed. Where water is hauled to the range, the kind of stock that will utilize the forage most efficiently should be chosen.

Because of the importance of water for range stock, this subject is discussed in some detail later in this chapter.

Economic Factors

Occasionally all other factors in selecting stock for a range must go unheeded in favor of certain economic considerations. For example, even though the hay produced on the home ranch for spring feeding is coarse and eminently suited for cattle, the winter range may be so well suited for sheep that these animals will clearly yield the largest returns. If, on the other hand, the range is so fenced that either sheep or cattle may be produced with little additional care, the character of the hay produced may be the deciding factor in selecting the stock to be grazed. Then, too, the custom of the community—whether it is predominantly a cattle- or a sheep-raising area—may swing the decision in favor of the more popular livestock enterprise. Such a decision is favored by the local producers, and it often results in advantageous exchange in help at critical periods and in cooperative use of needed equipment such as corrals and dipping vats.

Where the range-livestock enterprise is secondary to that of some other form of production, cattle can usually be handled with less close attention than sheep or goats and would therefore yield the largest profit.

Range Watering Places and Water Development

On many areas of the West, and even on farm pastures in the more humid midwestern states, the water supply may not be adequate for the number of stock the range will support. On some areas water supply is not available throughout the grazing season, and the stock must be removed even though the forage is nutritious and plentiful. On other units forage is wasted because of the absence of water until snow becomes available to permit temporary use of the range. Regardless of how abundant or desirable the forage may be, the animals grazed must have all the water they need without excessive travel. Accord-

ingly range stock water development has received much attention in recent years

Preliminary Considerations in Water Development

Good range management practices are not possible in the absence of adequate and properly distributed stock water Before a water-improvement program is undertaken, it is important to know what the water requirements are for the different kinds of stock and what constitutes satisfactory spacing of watering places

Water Development and Range Utilization No range can be properly grazed if distances between watering places are overly long Poorly watered ranges are usually heavily overgrazed near water and underutilized away from it The value of the unused forage can be closely estimated but damage resulting from overgrazing is difficult to appraise Financial loss also results when the animals lose weight or die because of inadequate water

In most instances the cost of water development on poorly watered ranges justifies the expense But if a range has sufficient water for the number of animals that it will support, additional water development will accomplish nothing A common error on many ranges is to increase livestock numbers as water is developed rather than to let the new watering places ease the pressure on previously overgrazed spots around old watering places Additional water development should chiefly be undertaken to improve distribution of the animals on the range and to use the range more efficiently and uniformly, thus insuring a more stable and profitable livestock enterprise

Water Requirements of Range Stock. Since the amount of water needed and its distance varies with the requirements of the different species of animal watering places obviously should be developed to meet the needs of the kind of stock chosen to graze the area.

Although many factors influence ingestion of water, particularly the kind of stock, character of forage, adequacy of salt, climate, and season, daily requirements are approximately as follows for cattle and horses, 10 to 12 gallons, for sheep and goats, 1 to 8 quarts Despite the influence of local factors, one can count on a daily water intake of 10 gallons for a mature range cow or horse and 1 gallon for a mature range sheep or goat

Cattle prefer to drink daily during the hot, drier summer months and approximately every 2 days in winter Bentley (5), working in northern California and using an automatic watering device, noted that all 16 cattle of mixed classes and ages grazed in a 537-acre pasture drank every day during the summer period, mainly during daylight hours.

In spring, when the forage is high in moisture content, cattle tend to go to water only once in 2 or 3 days

Horses and burros probably in part because they travel about more than cattle in their search for forage, prefer to drink every day throughout the year The large amount of mature, dry grass eaten by these animals in winter evidently accounts for their daily drinking habit at that season

Sheep can go several days to several weeks without drinking, depending on the availability of succulent forbs frequency of showers and dew, and temperature Jardine (*23*), working in Oregon, reported that sheep could be grazed with good results without water throughout the summer when subsisting on succulent range forage, provided they got some moisture from the atmosphere Even during hot, dry weather it is not necessary to drive sheep to water oftener than every third or fourth day

Spacing of Watering Places The chief objectives of undertaking a livestock water development program is to provide more even distribution of the animals over the range, to put to use areas whose forage would be wasted because of lack of water, to improve the quality of the water and to insure bigger and more sustained financial returns

Livestock do best when they can reach fresh forage fairly close to the water Cattle should not have to travel farther than 2 to 2½ miles to water on flat ranges free from rock sheep may travel 4 to 5 miles in such country

On rough mountain range, especially where rock outcrop is likely to cause foot soreness, cattle should not have to travel more than about ½ mile to water and sheep and goats not more than 1 to 2 miles Steers and dry cows can travel farther than cows with calves and dry sheep and goats can cover more ground than ewes with lambs and goats with kids Horses and burros can travel much farther between grazing grounds and water than all the other animals mentioned (*2, 24, 30, 36, 38*)

For best results to range and stock, permanent watering places should be so spaced that the number of animals using any particular water will not exceed the grazing capacity of the area within a reasonable radius On flat or rolling country not less than one permanent watering place should serve each 50 to 100 cattle In steep country, a watering place should be available to each 15 to 30 cattle

That good distribution of water greatly minimizes damage to the range was demonstrated by Talbot (*38*) On a range in New Mexico one unit had ample, well distributed water, and the other was poorly

watered. The degree of utilization, expressed in percentage, is shown in Table 18.

Even with proper water spacings some local injury to the forage will occur. Damage can be held to the minimum by appropriate handling of the animals, suitable seasonal use, ample, rationally spaced salt grounds, and in certain other ways indicated by the locality. In many instances permanent watering places may be interspersed with temporary watering centers to foster better livestock distribution.

TABLE 18

DEGREE OF RANGE UTILIZATION

Degree of Grazing	*Amply Watered* (Percentage of Area)	*Poorly Watered* (Percentage of Area)
Overgrazed	8	29
Moderately to closely grazed	69	44
Lightly grazed	19	19
Practically unused	4	8

PRACTICAL MEANS OF STOCK-WATER DEVELOPMENT

Additional range-stock water can be provided by natural improvement and artificial development. Natural water improvement includes cleaning out and preserving springs, seeps, and swamps; artificial development deals with building of wells and reservoirs.

DEVELOPMENT OF NATURAL WATER SUPPLY

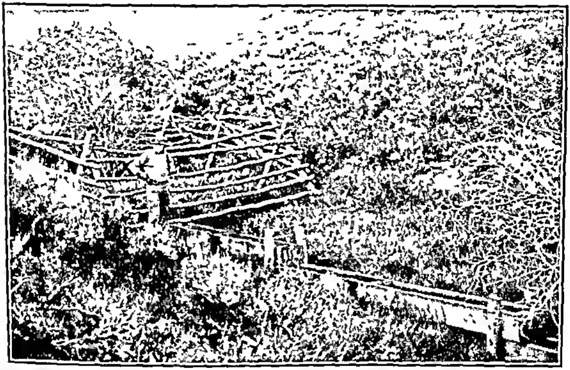
Except where streams supply the needed stock water, it will pay to develop most springs and seeps. Dangerous bog holes have sometimes been transformed into useful watering places.

Springs. A spring is a natural, fairly steady flow of subterranean water which reaches the surface through a crevice in the earth or rock. The flow from many springs can be increased by cleaning and protecting the springs from trampling by stock.

Before spring improvement is undertaken, the flow should be checked at various intervals during the grazing season to ascertain its quantity and reliability. The cleaning can best be done by digging out the ground about the spring. The excavating should be done near the point where the water emerges from the underlying rock, preferably down to bedrock. The excavation should be curbed or walled, preferably with concrete or other masonry, or with a wooden frame. An outlet pipe should be placed several inches above the bottom curbing. A closely fitting, removable wooden lid or flat rock should be used to

exclude debris. During freezing temperatures the pipe should be closed at the intake, then drained, and a spillway provided above the pipe outlet (2).

Where the flow is lost through seepage, as on hillsides, an open cut below the spring will collect the water, or the muck may merely be removed from the floor and a dam built, approximately a foot high, in order to raise the water level above the end of the outlet pipe (*18*).



(Courtesy of U. S Forest Service)

Fig 67. A spring, after having been cleaned out and curbed, was fenced as protection against trampling by cattle. Plank-built troughs set end to end conserve the water and keep the site dry.

Springs with large flow, or those in wet soil, should be securely fenced against stock (Fig. 67). The drinking trough should be located on well-drained soil several feet beyond the fence. Small to medium-sized, securely curbed and fenced springs have recently been developed at a cost of from \$100 to about \$250 each. In Oregon in 1937, (*36*) the average cost of spring development, including a concrete box catchment basin 3′ x 3′ x 3′ inside, was as follows:

8 sacks cement	\$ 8
50 ft. 1″ pipe at 10¢	5
Fencing material	10
Labor (excavating, fencing, setting troughs, etc)	77
Total	\$100

workmen to insure that all moving parts are in adjustment Effective operation and upkeep expense of the mill will be governed by keeping moving parts oiled and bolts tightened Where wind is not dependable, the pump is powered with a gasoline engine Suitable designs are available on the market

Water Storage Adequate water storage must be provided if a pumping plant is to be reliable During long calm periods or when breakdowns occur lack of storage facilities may cause serious livestock losses or heavy expense and inconvenience in hauling water A supply of water sufficient to take care of the animals for at least 1 week is advisable

Where possible, the well should be located somewhat higher than the reservoir to give the water the necessary fall Earthen, metal, cement, or masonry storage tanks are commonly installed, depending on materials available Good storage places can sometimes be made by blasting out rock on the side of a cliff or ledge and walling up the front with dirt, concrete, or masonry Combined storage and drinking tanks of concrete or steel are popular in some localities

Troughs and Tanks Adequate numbers of substantially built troughs tanks, and even reservoirs are indispensable to a properly watered range Trough facilities are chiefly determined by the available flow, character of the location, and number and kind of stock grazed There should be enough trough capacity to take care of all the animals drinking at any one time Since range sheep are usually handled in bands, more trough space is required for them than for cattle For a band of 1200 sheep a series of rectangular shaped troughs set end to end serve best When the tanks are placed so that the animals can water from both sides not less than 75 linear feet of space and a capacity of about 2000 gallons should be provided, even so, the band would have to be divided into several small flocks for watering

Troughs may be made of various materials in the vicinity of the watering place Where suitable timber is available, log troughs are often built Troughs made of planks 2 to 3 inches thick, mortised together, and braced with iron rods at top and bottom, and painted inside and outside, are common and satisfactory (Fig 67) For sheep, such troughs should be 10 to 14 inches wide, and for cattle, 14 to 16 inches Circular or rectangular tanks or troughs built of No 16 galvanized sheet iron are also popular, since they combine light weight, durability, and moderate cost (Fig *68A* and *B*) Concrete troughs or tanks, when properly installed and kept drained during cold weather are also durable

Height of the tank above ground and the footing around the tank

are important. For cattle, the top should not exceed 16 inches above ground, and for sheep, 8 to 10 inches. The troughs should be placed on substantial foundations on well-drained areas. Drainage of the soil around a tank can be improved by adding a mixture of broken rock,

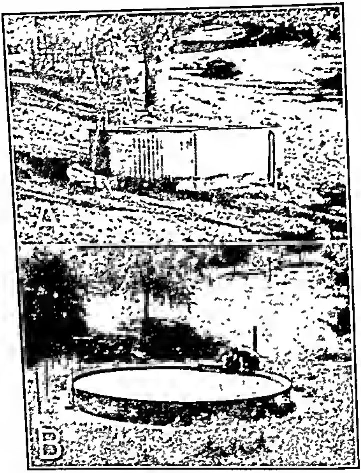


FIG. 68. Tanks commonly used for watering cattle and horses. *A*, Oval-ended galvanized sheet iron tank set on concrete foundation; *B*, steel-reinforced circular concrete tank located on a flat with a firm, well-drained soil surface.

sand, and gravel. To avoid formation of mudholes and waste of water, a float valve should be installed at one end of a partitioned-off and covered portion of the tank.

Tanks should be kept clean. The green algae, the most troublesome growth, can be destroyed by a small amount of blue vitriol, that is, crystalline copper sulfate. A teaspoonful of blue vitriol placed in a bottle with small slit in the cork to permit the solution to be liberated slowly will keep the algae out of a small tank for the season (*4, 37*).

Dams and Reservoirs. Where drainage and topography are favorable, dams and reservoirs may provide the cheapest supply of stock water (Fig. 69). Although some structures of this kind retain water for many years, they are usually built to supplement the more permanent water supply, since they are seldom long-lived.

The most common practice is to build dams or reservoirs across a channel. Often a reservoir is located between two drainage channels,

(Courtesy of U. S. Soil Conservation Service WN 53356)

FIG. 69. Earthen dam built at lower end of site close to center of sheep range. Such man-made watering places are essential to much of the western range region

and the water is carried to it by a ditch or through pipes. Diversion-filled reservoirs of this kind are less subject to damage from floods than cross-channel dams.

Reservoirs are most cheaply formed by building earthen dams, but concrete and masonry dams may be used where the soil is porous. Type of soil is important in obtaining a watertight reservoir. Clay soils with a goodly mixture of sand and gravel are most desirable; coarse-textured soils are unsuitable. Pure clays crack badly when dry and may slump when wet.

The ideal location of the reservoir is near the center of the range, easily accessible to stock with good approaches from many directions. Dirt for the embankment should be available. A flat or plateau may provide a good location if the reservoir is to be filled from a ditch that carries the water from a stream.

The size of reservoir will chiefly be determined by the period of

range use number of stock grazed frequency of filling loss from seepage and evaporation and rate of reduction in capacity from silting In the Southwest the reservoirs least likely to go dry from evaporation are 12 feet or more deep and as long as possible (*38*)

Although salting on a new dam to induce animals to trample and settle the embankment is desirable protection by fencing will be necessary later as discussed below

Spillways Regardless of how well built a dam may be, part or all of the embankment can be destroyed if adequate provision is not made to carry away the excess water

A common error is to build a spillway too small to allow for ready discharge of the water that rushes into the reservoir from a heavy rain storm Faulty construction of spillways that allows the water to cut under the floor may result in irreparable injury to the embankment Another error is that of locating the spillway at too high a level A good rule is to place the spillway low enough so that the water will begin to flow out when it gets within 3 or 4 feet of the top of the embankment

The capacity of the spillway is also an important factor In cross section the floor should be level to facilitate waste water passing through in a wide thin sheet Spillways cut through bedrock are preferable but earthen spillways are cheaper and serve fairly well, especially if sodded to check erosion

Pipe Lines. Most water sources such as springs seeps and reservoirs need pipe lines leading to troughs and tanks The lines may extend from a few feet to several miles and often require large investments For short distances, 1 inch pipe may be used but at distances of ¼ mile or more diameters of not less than 1½ to 2 inches should be employed Intake boxes and protective screens should be installed for all pipe lines Where heat is intense expansion joints should be put in where freezing occurs pipe lines should be buried Galvanized iron pipe is recommended and so are random lengths which run from 19½ to 21½ feet and are cheaper than uniform lengths The line should be laid as straight as possible to prevent clogging If necessary, clogging can be cleared by passing a No 9 wire through the pipe or sometimes by merely forcing air through it

Protection of Storage Units Most reservoirs should be fenced after the dam has settled Otherwise the width at the top bank is gradually reduced and the structure weakened Where gravity flow is adequate complete fencing of the storage unit is recommended Only where the storage unit is too low for the water to flow to troughs in desirable locations should the stock be allowed to drink directly from the reser

voir. Even so, fencing of critical parts of the reservoir is good practice For example, fencing to exclude stock from vulnerable spillways should not be neglected

Fencing allows better control of the stock, permits closing of the permanent water to correspond with the grazing seasons, conserves stock water for emergencies, and allows placing the troughs where animals will not mire down

The life of reservoirs often depends upon rate of accumulation of eroded material The best silt-control measure is to maintain the best cover practicable over the watershed This implies conservative grazing, proper seasonal use, and good livestock handling generally (*41*).

Cleaning out reservoirs that have filled with eroded material is sometimes cheaper than building new storage basins Where the existing reservoir is desirably located, removal of the silt deposits is justified even if it is somewhat more expensive than constructing a new one.

Where adequate range stock water is available well after the forage has passed the peak of its nutrition, a portion of the remaining feed can be utilized by supplementing the deficient nutrients

Supplemental Range Feeding for More Profitable Livestock Production

Supplemental range feeding provides livestock food on the range to balance nutritional deficiencies in the natural forage More broadly considered, complementary feeding includes those periods when the stock may be held on cultivated pasture, stubble fields, or in feeding yards when range forage is inadequate or unavailable

The nutritive levels of range food plants vary widely (Chapter 3), depending on stage of growth, inherent nutritional differences in species, fertility of the soil, and climatic conditions during and after completion of the growth cycle (*13, 15*). Still, yearlong grazing is a standard practice in much of western United States On many natural perennial grass ranges the forage, even in winter, supports the animals fairly well in average years, yet some supplemental feeding usually pays Frequent heavy fall and winter rains leach out certain nutrients, and the sun destroys some essential substances, notably vitamin A, from dry forage (*20, 43*).

In contrast to perennial grass ranges, grass stands such as occur extensively on California foothill and valley ranges sharply decline in food value early in the summer. The forage ripens in June, hence the animals must subsist on dry, bleached vegetation for several months unless other pasturage is available On these ranges supplemental feeding should usually begin in August and continue through January or until green feed is again plentiful (*16*).

Classification and Functions of Livestock Feeds

The chemical composition of plants and animals is remarkably similar Composition may be broadly grouped into three classes water, organic matter and mineral matter About 75 to 85 percent of the fresh weight of young growing vegetation is water, approximately 20 percent is organic matter, and about 1 percent is mineral matter A cattle carcass in good condition has about the same proportions of these compounds as green plants

Water Through water as the medium synthesized plant substances enter into various chemical reactions and recombinations and are transported as food and energy to various parts of growing tissues. Also by maintaining vegetal succulence, water content in wholesome plants is an index of high nutrition palatability, and food energy for animals Water in the animal body is as indispensable as in plants Among other things water serves as a dispersing medium in promoting cell reactions and in absorbing and dissipating the heat of these reactions Various chemical interactions in the animal are brought about by water it dissolves various organic and inorganic substances and stimulates chemical interaction

Organic Matter These compounds, which compose most living matter in plants constitute a major source of energy for life processes of plants and animals They may be broadly classed as carbohydrates lipids and proteins (Chapter 3)

Carbohydrates These substances—products of photosynthesis—are composed of carbon hydrogen and oxygen They account for about three fourths of the dry weight in plants and are the source of the major food energy of plants and animals The most important carbohydrates in plants are the simple sugars or monosaccharides notably *pentoses* and *hexoses*, the complex sugars or polysaccharides, such as cane sugar or *sucrose*, malt sugar or *maltose*, and milk sugar or *lactose*, and the pentosans starch and cellulose or fiber In living plant cells numerous pentose molecules tend to be linked to one another to form a polysaccharide molecule Slight though the chemical differences are between starch and cellulose they have profound consequences in animal nutrition The digestive tract, for example, secretes enzymes that hydrolyze starch to glucose or maltose units, to be utilized in body building or as a source of energy Cellulose (and pentosans) are of lesser food value than starch Their partial digestion is accomplished by bacteria that are present in the digestive tracts of grazing animals

Readily assimilated carbohydrates are supplied at critical periods on the range by feeding such cereal grains as corn, barley, oats, or sor

ghums, and by providing by-products such as dried beet pulp and similar local feeds

Lipids (Fats, Oils, and Related Substances) These compounds are also composed of carbon, hydrogen, and oxygen, and some closely related compounds have, in addition, phosphorus and nitrogen Being soluble in ether, they are referred to as *ether extract* Many of these compounds occur in small quantity in plant and animal tissues but perform indispensable functions The most familiar lipids (esters) are the fats and oils An oil differs little from a fat in its chemical nature, but the melting point is lower, usually occurring at ordinary atmospheric temperatures

Animals can convert carbohydrates into fats and digest the fats that they consume Fats constitute the most concentrated source of energy in animal and plant tissues Cereal grains notably corn, and also cottonseed, are rich in fats

Protein The term protein includes a large group of physiologically distinct but closely related substances This important group comprises all nitrogenous materials in feeds—termed *crude protein*—and furnishes nutrients for growth and repair of muscle, nerve, and glandular tissue—indeed, for the entire animal body Young forage and lean meat are rich in protein Occurring as natural combinations of amino acids, proteins contain carbon, hydrogen, oxygen, nitrogen, usually sulfur and phosphorus, and sometimes iron, which are essential constituents of all living plant and animal cells The animal obtains his protein in the form of essential amino acids from the vegetation it eats Protein may also be oxidized in the animal body to produce heat, or it may serve as a source of energy, costly though it is to meet deficiencies in carbohydrates and fats (*26, 28*)

Deficiencies of protein and such minerals as phosphorus and calcium frequently occur together Cottonseed cake and linseed meal are rich in protein and phosphorus, and roughages such as alfalfa and clover hays are high in protein and calcium

Mineral Matter More than 30 elements have been found in the higher plants and animals Calcium, phosphorus, potassium, chlorine, iron, magnesium manganese, sodium, silica and sulfur are found in the ash of all higher plants and animals, and aluminum boron, cobalt, copper, iodine, and molybdenum are usually present Most of the elements listed above are essential to plant and animal life, but few are so limited in pasture forage that they cause deficiency diseases

Calcium and Phosphorus Phosphorus is often deficient in mature forage, and the calcium phosphorus ratio is frequently disproportionate late in the growing season (*21*) These constituents are closely asso-

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Protein. The term protein includes a large group of physiologically distinct but closely related substances. This important group comprises all nitrogenous materials in feeds—termed *crude protein*—and furnishes nutrients for growth and repair of muscle, nerve, and glandular tissue—indeed, for the entire animal body. Young forage and lean meat are rich in protein. Occurring as natural combinations of amino acids, proteins contain carbon, hydrogen, oxygen, nitrogen, usually sulfur and phosphorus, and sometimes iron, which are essential constituents of all living plant and animal cells. The animal obtains his protein in the form of essential amino acids from the vegetation it eats. Protein may also be oxidized in the animal body to produce heat, or it may serve as a source of energy, costly though it is, to meet deficiencies in carbohydrates and fats (*26, 28*).

Deficiencies of protein and such minerals as phosphorus and calcium frequently occur together. Cottonseed cake and linseed meal are rich in protein and phosphorus, and roughages such as alfalfa and clover hays are high in protein and calcium.

Mineral Matter. More than 30 elements have been found in the higher plants and animals. Calcium, phosphorus, potassium, chlorine, iron, magnesium, manganese, sodium, silica, and sulfur are found in the ash of all higher plants and animals; and aluminum, boron, cobalt, copper, iodine, and molybdenum are usually present. Most of the elements listed above are essential to plant and animal life; but few are so limited in pasture forage that they cause deficiency diseases.

Calcium and Phosphorus. Phosphorus is often deficient in mature forage, and the calcium:phosphorus ratio is frequently disproportionate late in the growing season (*21*). These constituents are closely asso-

ciated in the animal body they tend to combine with and supplement one another A fairly close ratio must exist between calcium and phosphorus however dairy calves have been raised on a calcium phosphorus ratio as wide as 6 5 1 (*28*) Although a ratio of 1 or 2 parts of calcium to 1 part of phosphorus is ideal the percentage present is also important Deficiency of these elements produces characteristic

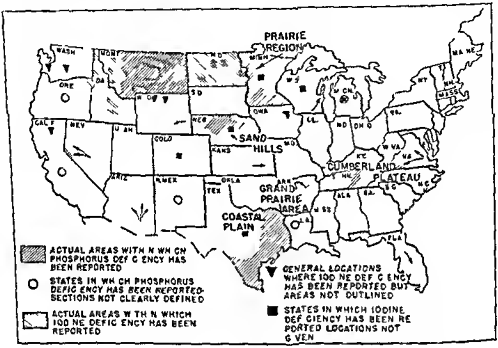

FIG 70 Areas of low phosphorus and iodine content as indicated by deficiency symptoms in livestock [*After Hartman* (*21*)]

symptoms of which rickets (alterations in the bones) is best known Range forage containing less than 0 05 percent of calcium and phosphorus is likely to cause deficiency symptoms in livestock Superior forage has about 0 25 percent or more of these elements (*17*, *22*)

Phosphorus deficiency has been reported in various parts of the United States (Fig 70) and on range lands of other continents (*8*)

Bone chewing by cattle is a specific symptom of insufficient phosphorus in its early and major stages (*9*) Where this occurs the rancher may follow one of four practices (*a*) supply feeds rich in phosphorus and other nutrients, (*b*) provide a phosphorus rich supplement as a concentrate, (*c*) fertilize the soil with phosphorus so the natural forage will supply the mineral needed, (*d*) supply the phosphorus in the drinking water (*6*)

Where the range forage is deficient in several essential constituents, including phosphorus, the best practice is to feed some supplement such as alfalfa hay or cottonseed cake. Where phosphorus constitutes the only deficiency, it is cheapest merely to supply this mineral in the drinking water or to feed finely ground, steamed bonemeal especially prepared for livestock.

This product contains about 30 percent calcium and 15 percent phosphorus. Fertilizer bonemeal is not eaten readily because of pronounced odor (25). Animals should be allowed to consume all the bonemeal they will take. The daily minimum requirement per 100 pounds of body weight is placed at 2.0 to 2.4 grams of phosphorus (*11*). In low phosphorus range areas a mature cow may take from 40 to 70 pounds of bonemeal a year (*9*). A mixture of bonemeal and salt is not recommended for animals will sometimes consume the mixture to get the sodium chloride when phosphorus is not needed or they may take more common salt than is desirable when they are hungry for phosphorus. Spent boneblack is another phosphorus carrying product available on the market. It is fed in the same manner as bonemeal but contains only about one half as much phosphorus. Either of these products brings about immediate stimulation of appetite and more effective use of the food consumed by phosphorus hungry animals (*34*).

The use of a fertilizer that is rich in phosphorus usually results in increased forage growth and in a nutritionally balanced feed so long as adequate phosphorus remains available to the vegetation (*29*).

A most recent and highly recommended practice of supplying phosphorus on the range is to dissolve this mineral in the drinking water (*6*). This may be done by putting 6.5 grams disodium phosphate (containing 20 percent P_2O_5) in 6 gallons of water. The resulting phosphorus concentration is adequate when the animal drinks the normal quantity of water.

Other Minerals. Sodium and chlorine, best known in combination as common salt, must usually be supplied to meet normal physiological requirements of range animals. Insufficient salt may cause depraved appetite, lusterless eyes, and a shaggy coat (*8, 9*). Sodium and chlorine occur largely in the intracellular fluid where they function to maintain osmotic pressure. Proper balance between sodium chlorine and water is important.

Iodine deficiency accounts for goiter, stunted growth, and poor reproduction of livestock. It is a problem in various northern areas of the United States, chiefly west of the 100th meridian (Fig. 70). It can be corrected by feeding iodized stock salt containing 0.02 percent potassium iodide (*26*). Commercially available iodized block salt usually contains the proportion of iodine needed. Nothing is accomplished by feeding iodine in localities where goiter has not occurred.

Copper, cobalt, and iron deficiencies occasionally cause malnutrition

in both plants and range livestock Mere traces of these elements are needed Iron and copper deficiency occurs in some localities of the United States notably in Florida, where it is especially noticeable in the suckling stage of animals, since milk contains little of these elements Recovery is rapid when livestock are fed all they will take of a combination of 25 pounds of red iron oxide and 1 pound of pulverized copper sulfate thoroughly mixed in 100 pounds of common salt (*28*) Green vegetation is rich in iron Cobalt deficiency in livestock, called "coast sickness" in New Zealand, "bush sickness" in Australia, and wasting sickness in Florida, may be corrected by using a cobalt salt as fertilizer on suspected pastures

Magnesium, manganese, potassium sulfur, and zinc are also apparently essential to grazing animals It is doubtful, however, if these minerals become limiting factors in the welfare of range livestock subsisting on natural range forage

Selecting Feeds for Supplementing Range Forage

Early spring, late fall, and winter are nutritionally most critical for livestock on perennial pasture, early spring and summer is most critical on annual ranges It is of great economic importance to keep the young animals growing and the breeding stock in thrifty condition at all times (*16*)

Classification of Common Feeds As a guide to the value of extensively available concentrates and roughages, the more common items of stock foods are classified in Table 19, according to Miller (27), in relation to their digestible nutrients

Among the most popular protein concentrates for range livestock are cottonseed meal or cake, and linseed oil meal Either of these is fed to cattle at the rate of 1 or 2 pounds per day (Fig 71), and to sheep at about ¼ to ⅓ pound a day Well-cured alfalfa and clover hays are high in protein, calcium and vitamin A, hence are especially valuable roughages for young and pregnant stock in winter

As a rule, it does not pay to feed stocker (breeding or growing) animals so heavily in winter that they greatly increase in body weight Young animals will build good frames and remain thrifty without much increase in weight during winter months When placed on green spring feed, thrifty animals will make remarkably rapid, cheap gains

Stocker animals are usually kept on a maintenance ration during winter months A 1000 pound cow on a maintenance ration requires about 6 75 pounds of total digestible nutrients per day, of which 0 6 to 0 7 pound should consist of digestible protein (*26*, *35*) The carbo-

TABLE 19

Pounds of Total Dry Matter, Ash, Digestible Nutrients, Calcium, and Phosphorus in 100 Pounds of Common Feeds

Feeds	*Total Dry Matter*	*Total Ash*	*Digestible Protein*	*Total Digestible Nutrients*	*Nutritive ratio**	*Calcium*	*Phosphorus*
Corn, dent, well dried	88.5	1.4	7.4	83.7	1:10.3	0.01	0.28
Barley, common, eastern	90.4	2.9	9.3	78.7	1:7.5	0.05	0.38
Barley, Pacific Coast states	89.9	2.6	6.9	78.8	1:10.4	0.05	0.40
Oats, Pacific Coast states	91.2	3.7	7.0	72.2	1:9.3	0.09	0.33
Wheat, Pacific Coast states	89.1	1.9	8.5	83.6	1:8.8	0.03	0.43
Milo maize, grain	89.4	1.9	8.7	79.9	1:8.2	0.03	0.34
Rice, grain or rough rice	88.6	5.0	6.3	69.1	1:10.0	0.05	0.21
Wheat bran, all analyses	90.6	6.0	13.1	70.2	1:4.4	0.12	1.32
Rice bran	91.1	10.8	8.8	67.7	1:6.7	0.08	1.36
Cottonseed meal or cake (43 percent protein)	93.5	5.5	35.0	75.5	1:1.2	0.24	1.11
Cottonseed cake (28 per cent protein)	94.7	4.4	23.1	70.9	1:2.1	0.17	0.64
Linseed meal, old process	91.3	5.5	30.6	78.2	1:1.6	0.33	0.86
Barley screenings	88.6	4.2	8.1	60.8	1:6.5		
Molasses, cane	74.1	9.4	0.9	56.6	1:61.9	0.56	0.06
Molasses, beet	80.6	10.3	2.5	58.8	1:22.5	0.05	0.02
Alfalfa hay, all analyses	90.4	8.3	10.6	50.3	1:3.7	1.43	0.21
Barley hay	91.9	6.8	4.9	54.1	1:10.0	0.27	0.29
Oat hay, wild	92.5	6.8	3.6	48.7	1:12.5	0.22	0.25
Sudan grass hay, all analyses	89.2	8.0	4.3	48.5	1:10.3	0.31	0.24
Bean straw, field	89.1	7.4	3.0	45.2	1:14.1	1.67	0.13
Barley straw	90.0	6.0	0.9	44.5	1:48.4	0.32	0.09
Corn silage, well matured, all analyses	28.3	1.7	1.3	18.7	1:13.4	0.07	0.06
Mangels, roots	9.4	1.0	1.0	7.3	1:6.3	0.01	0.03
Beet roots, sugar	16.4	1.1	1.2	13.8	1:10.5	0.03	0.04
Beet tops, sugar	11.4	2.0	1.9	7.4	1:2.9	0.15	0.04
Pumpkins, field	10.4	0.9	1.3	9.0	1:5.9		0.04
Bur clover, green	20.8	2.3	3.7	12.8	1:2.5	0.25	0.07
Filaree, green	16.3	3.0	2.4	8.8	1:2.7	0.29	0.07
Grasses, mixed, immature	29.7	3.0	3.6	20.2	1:4.6	0.24	0.10

* Nutritive ratio shows the proportion of digestible protein in roughages and other feeding stuffs. It expresses the numerical proportion between the digestible protein and the digestible carbohydrates plus the digestible fats times 2.25. It is calculated as follows:

$$\frac{\text{Digestible nitrogen free extract} + \text{digestible fiber} + (\text{digestible fat} \times 2.25)}{\text{Digestible protein}}$$

hydrate requirements vary according to the energy expended in gathering food. Growing, lactating and pregnant animals need more and different feed—higher in protein among other things—than do mature nonpregnant individuals. A ton of good hay per cow is considered a standard allowance for about 100 days during the nongrazing season.

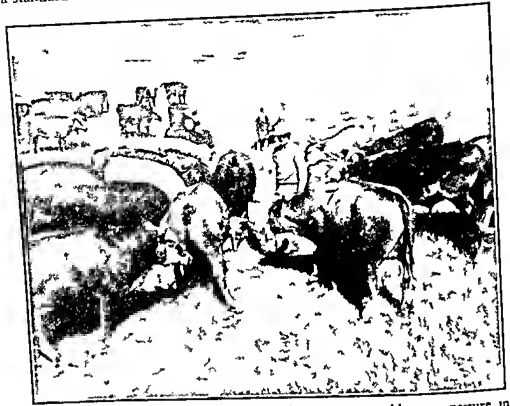

FIG. 71. Feeding nuggets of cottonseed cake to steers on bluestem pasture in early autumn. Although bluestem pasture is ideal while succulent, it is deficient in protein and certain other nutrients after maturity, as are many other grasslands. Manhattan, Kan. (Courtesy of Hale B. Rannells, who is feeding his cattle.)

The kind and amount of feed supplied to stocker animals during winter varies with locality. For sheep alfalfa hay ranks high. When hay is expensive, oats, corn, cottonseed cake, and wheat screenings may be fed with local inexpensive roughages.

Use of Silo. The possibility of conserving livestock foods for winter by storing roughages in a trench silo should not be overlooked. Various cheap feeds that might otherwise be wasted can be siloed.

Cactus and Soaptree Yucca as Emergency Feeds. Droughty seasons occur so frequently in the Southwest that stockmen often graze cattle and sheep in winter with good results on cactus (*Opuntia* spp.) and use soaptree yucca (*Yucca elata*) as silage. Heavy losses of

stock in poor forage years have been prevented by use of these plants (*39*).

Grazing Upon Cactus. Cacti vary from flat-jointed, relatively spineless plants to spiny forms of prickly pear and to those with cylindric joints of the heavy-fruiting chollas. Several species of these prickly plants are useful as emergency stock food. Spineless cactus has been cultivated and hand-harvested to some extent for stock food. In natural stands the thorns are singed off with a cactus torch burner; one man in a day can singe stands weighing from 7000 to 11,000 pounds, or the equivalent of from 1600 to 2500 pounds of dry matter (*14*, *39*). Feeding singed cactus on the range greatly increases the utilization of the associated grasses and other plants. Since cacti are high in percentage of carbohydrates and low in percentage of protein, cottonseed cake or other protein-rich feed should be supplied (*19*). Another method of utilizing cacti is to cut up the joints with a pear-cutting machine. Singeing cactus plants as they stand on the range is least expensive and most convenient, but the operation must not be done so closely as to destroy the outer living branches and trunks or remove the fruit-bearing branches.

Feeding Soaptree Yucca Silage. Soaptree yucca occurs from western Texas to southern Arizona. Although the green leaves and young flower stalks of this plant are grazed by cattle to some extent before the spring growth of grass is available, the greatest value of the tree is for silage for use during emergency feed periods (*12*). If fed for many weeks, some concentrate, such as cottonseed cake, should be supplied, because the protein content of soaptree is low. From 15 to 20 pounds of chopped soaptree yucca, with 1 to 1⅓ pounds of cottonseed cake or meal daily, will maintain breeding cows in thrifty condition. Ordinarily, the cost of this feed combination varies from about $1.50 to $2.00 per month. Only the larger plants should be harvested, but a few adult plants should be left for seed production.

Computing Tonnage of Haystacks. It is important to know in advance of the feeding season the amount of hay on hand and to be able to compute the tonnage in haystacks. If hay alone is fed, one should plan on feeding about 20 pounds per mature cow daily; that is, per 1000 pounds animal weight. An additional 20 percent, on an animal weight basis, should be fed to young growing stock.

The Faye-Bruhn rule, or "rule of two" (*1*), provides a satisfactory means of stack measurement. Simply subtract the width (*W*), expressed in feet, from the "overmeasurement" (*O*), multiply this result by the width, and divide by 2. This computation gives the cross section of the stack. Then multiply the cross section figure by the

length (L) to get the cubic contents of the stack. The formula is expressed thus:

$$\left(\frac{O-W}{2}\right) W \times L$$

When the cubical content of a stack is determined, it is necessary to know the number of cubic feet that represents a ton of hay. Figures of 450 cubic feet per ton of alfalfa and 512 cubic feet of grain and volunteer hays represent averages. Age, or compactness of stack, and moisture content of the hay are the two most variable factors affecting weight; adjustments therefore, may be made locally for these factors in the computations.

Range Sanitation

Common to all range lands and in the interest of the livestock industry generally, are the laws pertaining to range sanitation. Although these laws vary somewhat in the different states, their aim is to protect the livestock industry from spread of contagious, communicable, or infectious diseases. All animals brought into a state, or into a disease-free district within the state, are subject to health inspection and clearance through issuance of a health certificate by qualified authorities (*40*). In cattle, the most common diseases guarded against are foot-and-mouth, tuberculosis, Bang's disease, scabies, blackleg, and tick fever; in sheep, inspection is chiefly for foot rot and scabies.

On Federally owned lands sanitary regulations are enforced by Federal administrative agencies. On the national forests carcasses of all animals that have died from contagious or infectious diseases are burned, and those that have died near water must be immediately removed and burned or buried. Owners of deceased animals are notified to carry out regulations. Burning of full-grown cattle is not a simple matter (*42*).

> The Forest Service recommends that a hole be dug close to the carcass, about 2 feet deep and large enough to contain the body. Two or three small ditches are dug sloping from the ground surface into the hole to produce a strong draft. The hole is filled with dry wood to give maximum draft, then the animal is rolled onto the pile and additional wood placed on and around the carcass. When burning is completed, the hole should be filled in with the excavated soil to cover the bones.

In the next chapter is discussed husbandry practices of the different kinds of livestock on the range.

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Chapter 15

MANAGEMENT OF CATTLE, SHEEP, AND GOATS ON THE RANGE

In this chapter we consider management practices that apply to the handling of cattle, sheep, and goats under range conditions. We also deal with breeds as they relate to range use, and with the handling of livestock on the diverse southern ranges.

Range-Cattle Husbandry

The success of a ranching enterprise depends on the suitability of the management practices adopted.

Ranch Organization

Cattle ranches vary greatly in size and in the nature of their organization. Some ranches have abundant cultivated lands upon which hay and/or cereal crops are grown for both the market and the livestock. Some of these ranches keep up to 50 cattle to utilize the rougher lands, seasonal stubble, and excess fodder. These are known as diversified ranches. Other ranches may have more than 1000 cattle, and practically all crops grown are utilized by the animals. Ranches of this kind are called "cow" or "specialized" livestock ranches.

Operating methods are little influenced by size of the herd or diversity of the ranch. The more common forms of organization are: (1) *steer ranches*, where the operator buys either weaners or yearling steers—usually in the spring—grazes the calves for a year or more or the steers for the season only, and sells them as butcher beef; (2) *cow and calf ranches*, where a breeding herd is maintained, and the calves are sold either as "vealers" or at slightly greater age—usually in the autumn—as feeders; (3) *mixed-herd ranches*, where the calves are grazed, generally beyond the first year of age, when the steers, some heifers, and the culled cows and bulls are sold, either to the butcher trade or to feeders for finishing.

Various sections of the range-cattle country specialize more or less in one of these operations, but the mixed herd plan of operation is the

most common (15) Cows of breedable age compose about half of the mixed herd, breeding cows make up most of the herd where vealers or short yearlings are sold In these operations the breeding season is usually so gauged that the calves are dropped in the spring when lush feed and mild weather prevail

Range Cattle Breeds

The success of a cattle ranching operation is much influenced by what breed is selected to harvest the forage crop Where feed is abundant yearlong any of several popular beef breeds will do well though some will usually prove more profitable than others Where the forage is relatively sparse, an especially hardy breed with good rustling qualities must be chosen But, regardless of breed superiority, ample nutritious feed must be available at all times to insure a high percentage of offspring to keep the animals in thrifty condition, and to make for good, marketable individuals

In referring to livestock, the terms 'kind and 'breed' of animal are sometimes confused Kind of stock refers to the species, such as cattle or sheep, breed to the race or group of a common descent The Hereford race of cattle and the Merino race of sheep are examples of familiar breeds. On the western range, these breed characteristics are in demand strong breeding qualities, capacity to withstand inclement winter weather with minimum supplemental feeding, desirable handling characteristics, and good response in the feedlot (5)

The western grower raises cattle for beef production The original Spanish 'high-off the ground" animal, usually of mixed breeding, has given way to the more blocky, distinctly beef type, mostly of the temperate zone breeds that originated in Great Britain All the better beef breeds are now found in the West, because no one breed combines all desirable characteristics

In the last half century, breeds of beef cattle have become rather concentrated geographically, largely through trial and-error practices. Arranged in order of popularity, the major beef breeds in the western range country are Hereford, Shorthorn, Aberdeen-Angus, Galloway, and Brahman The population of Brahman is increasing rapidly in the warmer regions of this country

The Hereford is the second largest among the older breeds It is noted for excellent beef type, hardiness, rustling qualities, good grazing capacity, and strong constitution Its chief weakness is its low milk production Where the forage is sparse and winter weather severe, this breed is unsurpassed (30)

The Shorthorn is the largest of our cattle It is the most popular

breed in farming districts, indeed, it exceeds in numbers all other beef breeds in the United States and is second in the West Shorthorns have quiet dispositions but do not mature as early as Herefords or Aberdeen-Angus Where pasturage is abundant they are unsurpassed for beef production, and they exceed all other beef breeds in yield of milk However, since they are not as good rustlers as the Herefords they are not likely to replace Herefords on the western range

The Aberdeen Angus, though not as large as the Hereford or Shorthorn, is a superior beef animal This breed is polled and black, both of which are dominant characters The black color is a disadvantage in crossbreeding, for the offspring from red or white cattle give the appearance of having dairy blood Angus cattle are not especially popular on the open range, because their nervous disposition makes them difficult to handle In recent years, however, Angus cattle have increased locally, notably in parts of the Southwest

The Galloway ranks high in hardiness and rustling qualities Being polled and black, it resembles Aberdeen-Angus but is smaller Galloways too have a nervous disposition and are difficult to handle on the open range, also, calves from red or white cows are likely to appear to carry dairy blood

The Brahman, characterized by a large hump on the withers loose folds of skin forming the dewlap and navel, and long, drooping, pendulous ears, was introduced from India (Fig 72) Although not as good a beef type as the breeds discussed Brahmans are hardy, excellent rustlers endure heat well, and are resistant to external parasites such as the fever tick (Chapter 2) Despite the fact that they are more nervous than any of our temperate zone cattle breeds, bulls carrying one half of Brahman blood are being crossed to advantage with temperate-zone beef breeds in the hotter and more humid areas of the United States notably the Gulf region (*39*)

The Santa Gertrudis, the first strictly American breed of beef cattle, is resistant to subtropical climatic conditions This large, dark-red breed was developed on the King Ranch at Kingsville, Texas, by crossing the Shorthorn × Brahman It has not yet been distributed for wide use

Crossbreeding Practices

Crossbreeding is the practice of mating different breeds, or sometimes different species The resulting offspring is called a 'crossbred' Rational crossbreeding results in increased thrift and better adaptation of desirable characteristics through hybrid vigor (heterosis) Crossbreeding may combine desirable features of breeds or types, such as the

polled character and the superior flesh of Aberdeen Angus, the milking capacity of Shorthorns, the heat endurance of Brahmans, or the rustling qualities of Herefords (*14, 16, 23*) The most common and perhaps most successful crossbreeding on the western range has been Shorthorn

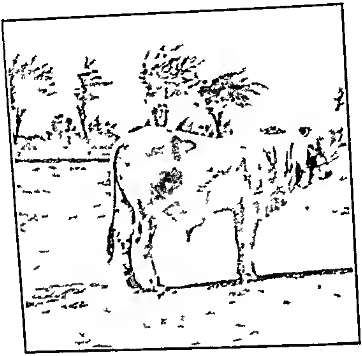

FIG. 72 Young Brahman bull Note prominent hump on withers large folds of skin forming dewlap and navel and drooping pendulous ears Although not a superior beef type Brahman bulls are useful in introducing hardiness into herds. They are most popular in regions of warm and moist climates.

bulls × Hereford cows, Brahman bulls × Hereford, Shorthorn, or Aberdeen Angus cows, and under farm pasture conditions, Aberdeen-Angus bulls × Shorthorn cows

Building Up Herd

The owner of a herd of poor or mediocre cattle has a choice sell all the cattle and buy good-quality heifers, or retain the better cows and breed them to purebred bulls of the specific breed, this procedure entailing less initial expense

Selection of Bulls In the earliest development of livestock breeding, choosing the parents to be mated was essentially based on general external appearance of the sire, that is, on the *phenotype* This practice resulted in many disappointments since a large proportion of the offspring do not inherit the characters most desired Now the wise

rancher buys only purebred bulls of good conformation, for he knows that *genotypic* selection—made according to approved lines of descent—results in transmission of maximum proportions of their external appearance

That the bull is an extremely important factor in improving the herd cannot be overemphasized Annually, the cow influences one offspring only, whereas the bull affects 20 or more calves The quality of the bull, good or bad, is at once reflected in the oncoming generation

In selecting a bull two factors especially must be kept in mind ancestry and appearance Both are important but the real test of the sire is *breeding performance*, which is determined by progeny testing Most ranchers buy yearling bulls in lots of 5 to 25, but they should not be used until they are 2 years of age Their best period of service is about 5 years

The more enterprising rancher selects the better of his young bulls for breeding to 5 or 6 cows of good, average quality Once he knows which animals produce the most superior offspring, he can mate the most prepotent bulls with the better cows It is from this lot that the replacement heifers should be chosen (*28*)

In improving the quality of the range herd, the essential features towards which to build are size of body frame, good bone and ruggedness Low blocky body and uniformity of type are also desirable traits Uniformity in color and markings, although desirable are of secondary importance

Culling of Herd Removal from the herd of the less desirable cows is second in importance only to that of breeding to good bulls Good judgment calls for the culling of all dry cows, nonbreeders poor milkers, long headed, thin necked shallow bodied, light hind quartered, and old cows (*14*) Wild cows should also be disposed of, since they tend to excite otherwise quiet cattle Weaning time, when the calves are 6 to 8 months old is an ideal time for selection of superior cows and for culling Culling out of not less than about 15 percent of the cows per annum is an approved practice in some highly successful range cattle localities (*28*)

Percent Calf Crop The chief function of a range cow herd is to produce a large percentage of quality calves The principal factors controlling the calf crop are (1) ratio of bulls to cows and their handling on the range, (2) season of breeding, (3) efficiency of culling the breeding stock, (4) control of infectious diseases affecting reproduction, and (5) the plane of nutrition of the animals

On the open range, 1 vigorous bull between the ages of 2 and 6 years should be provided for each 25 cows In very rough country

a ratio of 1 to 20 is desirable. On good, small, fenced pastures a vigorous bull will serve no less than 50 cows. Under range conditions it is important that a rider keep bulls and cows well distributed. On large, fenced areas it is good practice to rotate the bulls. Half of them may be placed with the cows for some 15 days, they are then removed to a good pasture and fresh bulls are simultaneously placed with the herd. As the breeding season advances all the bulls are kept with the herd.

As stated earlier, the season of breeding should be so gauged that the calves are dropped when green spring feed becomes available, and the differential in age of the calves should not exceed 120 days. Since the period of gestation in cattle is 9 months, the bulls are placed with the herd about that many months before the time when the earliest calves should be dropped.

The percentage of calves obtained varies widely in different sections of the range country. In Wyoming, for example, the calf crop varied from some 30 to 95 percent, with an average of about 57 percent, in the areas studied; in Colorado the average was around 57 percent, on prairie range 56 percent, on fenced pasture 73 percent. In Texas the range was from 51 to 94 percent (*16*). For some regions in California, Fluharty (*12*) concluded that less than a 70 percent calf crop entailed a financial loss.

The percentage of calves is obviously influenced by the health of the herd. Contagious abortion, known as Bang's disease, *brucellosis*, or *Brucella* infection, is the most common disease affecting calf production. Infection is spread largely through feed and water contaminated by discharges from the cows—rarely from the bulls. The disease is characterized by abortion of fetuses from early to late stages of pregnancy and by placentas commonly retained. Veterinary advice should be secured where the herd is suspected of having this disease.

Another disease, *trichomoniasis*, may also seriously influence the calf crop. It is a venereal disease transmitted by the bulls. Infected individuals should be disposed of. It is characterized by very early abortions of decomposed fetuses. A veterinarian should be consulted also where this disease is suspected.

Creep-Feeding of Calves. Creep-feeding of nursing calves provides concentrate and/or hay placed in a self feeder, trough, or rack within a small enclosure. Openings are made in the fence big enough for the calves to enter but too small for the cows. Calves that are to be fattened or slaughtered young are often creep-fed in the West to induce faster finish and to shorten the feeding period after weaning (*14*). When the natural forage is limited, creep-feeding indirectly helps the

cows, since the calves suckle less in the latter part of the nursing period. Creep-fed calves are also easier to wean; since they have become accustomed to a suitable ration, they miss their mothers less and have little or no setback.

Creep-feeding has been successful in years of limited forage, in areas where the range is fairly heavily stocked, where feed is partly home grown and not high priced, or where the available market will pay for calves in better flesh (*13*). It is doubtful that creep-feeding is justified in localities where the pasturage is abundant and of good quality and where the cows have the inherited trait of adequate milk flow (*20*).

Maintenance of Nutritional Level. Maintenance of an efficient herd requires that the range be kept highly productive. The most critical feed period is usually between weaning time in the autumn and the next calving period in the spring. During this interval cows and heifers should gain in weight; otherwise they will be thin and weak when calving. Supplemental feeding of hay and/or concentrates on range or feedlot at this season is of utmost importance (Chapter 14). If hay is fed exclusively, about ¾ ton will be required per animal by weaners, 1 ton for yearlings, and 1½ tons for cows for 120 days—the length of feeding period common in the West.

Each year large numbers of breeding cows and younger cattle are wintered on the open range. In regions where winter weather is severe and snowfall is sometimes heavy, feeding of about 1 pound of cottonseed cake, or the equivalent in grain, is often necessary to prevent losses and to maintain body weight. The forage near naturally sheltered areas should be reserved for the weaker cattle; but if no such places are available open sheds should be built to provide shelter (*34*).

On any range it is essential to determine the number of cattle that may be grazed without injury to the cover. As discussed in Chapter 16, grazing capacity estimates should be based on the forage yield in slightly below-average years rather than in seasons of exceptionally good growth. On all ranges a reasonable amount of the current growth of the dominant forage grasses should be left to insure vigorous growth in the following season.

Stock Trails, Driveways, and Bridges

Trails, driveways, and bridges must sometimes be constructed to get cattle to and from distant winter, spring-fall, and summer ranges. In the early stages of the cattle industry, trailing and driving the animals long distances was the general practice. Today, livestock are carried by railroad and trucks, but large numbers are still trailed many miles each year, notably to national forest summer feeding grounds and to

winter range Where the stock can be moved unhurried along routes having ample forage, trailing will presumably not diminish, for economic reasons

Trails and driveways are often constructed in brushy, heavily timbered country or on steep hillsides A large mileage of driveways is cleared through brush and timber, notably on the national forests, where the herds and bands may travel to and from the summer range in a leisurely way (37) This trail and driveway construction has reduced death losses of stock in transit and minimized injury to good range over which the animals would otherwise have to be trailed On cattle range, areas of superior forage have been made available by building trails where down timber, dense brush, ledges, or steep slopes had previously kept the stock out.

The construction of bridges over streams too deep for crossing by stock has likewise made good range available Bridge construction has often made possible the grazing of range units in the season when the forage is of highest nutritive value Under such conditions, bridge-construction costs are soon written off

Controlling Distribution of Cattle on Range

Once the cattle have reached the range they must be properly distributed to utilize the forage as uniformly and efficiently as possible Spotty overgrazing and too light cropping must be avoided to the greatest extent possible The most ideal distribution of cattle will come to naught if the range is overstocked Careful inspection near the end or shortly after each current grazing season should check the degree of utilization on each range unit These observations should point the way to needed adjustments in the livestock numbers grazed and in their management in the next season, and possibly thereafter

Range areas of rough topography particularly demand the use of all practical methods that are likely to obtain the desired distribution of cattle over the range This can be done by direct and indirect control

Direct Control This is accomplished by herding and fencing

Herding Herding is the control of the animals by guiding their direction and movements on the range with the view to procuring grazing where and when desired

Cattle are herded on the range by riding Although the daily movements of cattle do not require as close guidance as those of sheep or goats, the services of an experienced herder or rider are necessary

Some of the more important duties of the herder are to (1) prevent the cattle from straying from the range on which they should graze,

(2) guide the animals to areas where the feed might otherwise be wasted; and (3) prevent the cattle from concentrating on accessible areas where overgrazing might occur. The herder must also keep needed fences in repair and prevent the cattle from drifting to elevated range too early in the season. He may occasionally have to drive the cattle off areas harboring poisonous plants, place salt on the range at the proper time, and head the cattle to remote watering places which they might not otherwise find. He assists in rounding up the cattle for branding, castrating, vaccinating, and dehorning and in sorting out the beef animals for market. At the close of the summer grazing season he helps drive the cattle to the home ranch or to the winter range, where his duties start all over again (*18*, *30*, *34*, *37*).

Fencing. On some ranges, well-constructed and properly located fences are the most effective and least expensive means of controlling the cattle. The most important function of a range fence is to provide control vital to the animals and the range. This entails the placing of fences where they will prevent trespassing of the animals on range owned by others or set aside for other operations. Fences also serve to (1) facilitate distribution of the stock; (2) prevent the cattle from drifting to the more elevated ranges too early in the season; (3) carry out a plan of deferred and rotation grazing as a means of range improvement; (4) prevent losses of stock by enclosing poisonous-plant areas and bog holes, (5) segregate the cows from the rest of the herd by fencing off one or more breeding pastures; and (6) facilitate handling of the cattle by building needed corrals (*34*, *37*).

Fences constructed for these purposes are designated as follows: line or boundary fence located between two ranges, as along ridge tops, to prevent trespass; drift fence, an incomplete structure, such as across a canyon or a valley floor, to prevent the animals from passing from one area to another; and division fence, located within a range unit to facilitate distribution of the animals.

The most widely used fencing material for cattle is barbed wire; the fence is commonly of 4 wires fastened to wood or steel posts. In wooded regions and where deep snows occur pole fences are popular, the poles being hewed to fit securely together at each end. On cattle and horse range, the electric fence, consisting of a single wire supported by widely spaced posts, is rapidly gaining in popularity where a temporary fence is needed. Its construction requires little labor and material. As the source of current a battery may be used—in fact, is preferable—but a hook-up with a standard power plant with a transformer attachment is sometimes employed (*34*). This type of fence is also effective for hogs but not for sheep and goats. For those,

woven wire fencing is used most To avoid relocation of fences, a good plan of management should be worked out for the entire range area before fence building is undertaken

Indirect Control. Indirect control of cattle is carried out by salting, and by proper distribution of watering places which is the more effective

Stock Water and Water Development Water is as essential to the welfare of livestock as feed Since cattle will seek watering places, these can be used to control animal movements Where the distance between watering places is excessive, the flow of springs and seeps may be improved and the water conserved in tanks In some localities new sources of water may be developed (Chapter 14)

Salt and Salting Grazing animals need more salt (sodium chloride) than they can get from the vegetation upon which they ordinarily subsist Both sodium and chlorine are essential to the health of livestock and other animals (27) Babcock (*1*) noted that dairy cows developed an abnormal appetite for salt within 3 weeks after they were deprived of it As the experiment advanced, the animals had little appetite, lost much weight, had lusterless eyes, a rough coat, and finally collapsed Recovery was rapid when salt was supplied

Further evidence of the need of salt is the fact that animals will consume about the usual amount even when using alkali licks, which, in general contain little or no chlorine (*21*) Chlorine enters into the formation of hydrochloric acid in the gastric juice and is essential in building of blood When adequate salt is supplied, animals develop better, are more content, easier to handle, and less likely to acquire a depraved appetite

Amount, Kind, and Distribution of Salt Salt should be placed where feed is plentiful It can be put out as soon as the cattle are brought to the range, because this will help 'locate' them It should not be placed on range that is not ready for grazing, on overgrazed units, where patches of poisonous plants occur, on steep areas, and, as cattle are likely to become footsore, on rocky areas Also, salt should be removed from localities that have been sufficiently cropped, or the animals will linger there too long It is a good rule to place salt about ½ mile from water, not closer, but always where cattle can get to it easily The more desirable locations are accessible benches, ridges, gentle slopes, and openings in brush or timber

The number of salt grounds that should be established on a cattle range unit varies with many factors notably topography, distance between watering places, grazing capacity of the range, and character of the forage The principle to follow is to establish enough salting

places to obtain the best possible distribution of the cattle and at the same time prevent range depletion in the vicinity of the salt grounds. On yearlong level or gently rolling range of medium-to-low grazing capacity, salt grounds may be placed about 2 miles apart (*10*). On moderately high-capacity range the salt grounds may be 1 mile apart, or 1 salt ground to approximately 600 acres. On short-season range this might be equivalent to 35 to 60 cattle per salt ground. In rough mountain country, where salt grounds are used for only a few weeks, the distance between them should not exceed about ½ mile, each one to serve from 15 to 25 cattle. On any range it is better to have too many than too few salting places.

The amount of salt to put out on each salt ground should be determined by the grazing capacity of the range concerned. Allowance should be made for weathering during the rainy season.

Although the amount of salt eaten by cattle varies with the season and the character of the forage (*33*), 2½ pounds per head per month should be allowed on the range when the feed is succulent. On mature forage, including winter range, about 1½ pounds per month is usually sufficient (*10*). On yearlong ranges a total of 25 pounds per cow is fully adequate.

Many different forms and market grades of salt are used, ranging from "rock" salt as it comes from the mine to evaporated or crushed (sacked) or block (pressed) salt. Cattle seem to prefer the softer crushed or granulated salt from which they can quickly obtain the amount desired; it gives all the salt-hungry cattle a chance to get their *quota*. If salt logs or boxes are used, granulated or crushed salt is preferable; otherwise block salt should be supplied, but without "medication," or sulfur, since these additions seem to serve no useful purpose (*34*).

Salt can be hauled during lax labor periods in summer or fall and cached in a substantial storage box located conveniently for its distribution later. A pack animal or two-wheel cart is an effective means of distributing salt on rough pasture.

On relatively large range areas it is helpful to prepare a written salt plan and to number or name some of the salt grounds on a signboard. The salt grounds also may be entered on a map (Fig. 73) for convenience in finding them (*10, 18, 30*). By numbering or naming some of the salt grounds, the rest may be located readily by familiar landmarks. The signboard contains essentially the same information as the map, except that approximate date for distributing the salt may also be stated, such as "No. 4 $\frac{6-10}{80}$"—number (or name) of the salt ground,

date for distributing the salt as the numerator, and pounds of salt as the denominator

A properly executed salt plan implies that salt grounds will be suitably distributed over the range, that the poundage of salt will be

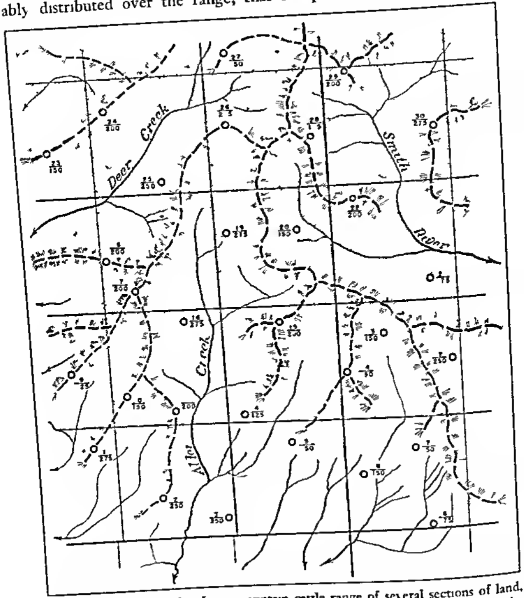

FIG 73 Sample salt plan for a mountain cattle range of several sections of land, showing drainage main ridges salt ground locations and amount of salt to be put out as judged by abundance of forage and acreage concerned Shaded portion of sketch indicates area that lies at or above 9000 feet in elevation and where salt is put out latest in the season

O = Salt ground locations

$$\frac{1}{175} = \frac{\text{Number of the salt ground}}{\text{Pounds of salt}}$$

determined by the amount of accessible forage; and that the salt will not be put out on any range unit until the forage is ready for grazing.

Cattle Grazing in Southeastern States

Because of the growing importance of cattle raising in the southern states and the vast diversity of local conditions there, it seems desirable to discuss these topics in this chapter.

The South is an extensive and versatile empire, and its beef-cattle industry is large and is becoming more important.

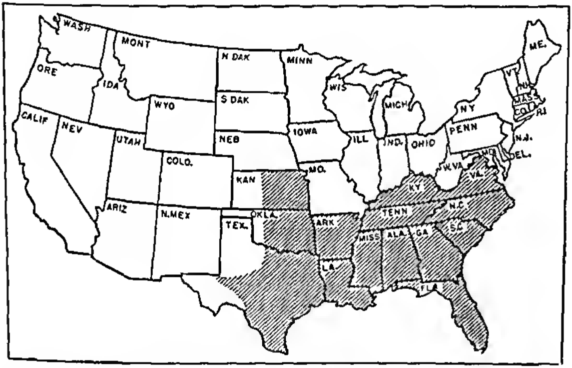

Fig. 74. Map showing the province designated as "the South," a region that receives fairly heavy, well-distributed rainfall and has a long growing season. Livestock production is increasing in importance as diversified agricultural practices gain in popularity.

The South includes all of the Cotton Belt proper, the mountainous areas adjoining, a portion of the Appalachian Mountain region, and the Cumberland-Allegheny Plateau (Fig. 74). It is characterized by mild winters, long, warm summers, and abundant rainfall which is well distributed through the year. Most of the region has a growing season of more than 200 days.

General Considerations. Agricultural production has gradually shifted from the once predominant row crops of cotton and tobacco to more diversified land use. Grass and livestock production are on the increase. In 1948 there were some 13 million cows and calves and 1,868,000 sheep, in addition to many other animals, in the eleven

southern states. To provide grazing and fodder for the stock, this region produced hay crops on 9,037,944 acres, forage on 13,962,663 acres of permanent pasture, and other stock foods on 26,288,311 acres of land used more or less for livestock (22). Even so, some hay had to be imported.

The cattle are handled according to the conditions of the locality. On the prairies of Oklahoma, Louisiana, southern Texas, and southern Florida they are run in large herds, much as in the West, but in the Cotton Belt proper usually only a few cattle are kept on each farm. Here yearlong grazing on forest range, with a minimum of husbandry, is a common practice. In this region extensive crossbreeding with Brahman bulls has resulted in hardier offspring.

Profitable grazing, under good management, is obtained on the cleared or cutover forest lands, of which there are some 200 million acres. The best grazing period on these areas is about 3 months in the spring and a few weeks in early autumn. For the rest of the year the cattle should be maintained on cultivated pasture and harvested crops. Among the better domesticated forage plants for reseeding piney-woods pasture are Bermuda and Dallis grass on the more productive soils, Natal grass on the drier and poorer sites, and carpet grass on some of the moist flatwoods (2). In the extreme South pearl millet, Napier grass, and St. Augustine grass are well adapted (Chapter 11). Lespedeza, or Japanese clover, is used to advantage for hay and pasture over most of this region.

Although grazing on cutover forest land has been practiced since Colonial days, there have been conflicts between the timber producer and the grazier. This conflict is chiefly the result of setting uncontrolled fires that have destroyed much timber. At present, most farm woodlots are so badly trampled and overgrazed that they produce little forage, and timber is not becoming established. These malpractices are serious, since normally the southern forests are five to ten times more profitable for growing timber than for grazing (8). Fortunately, a combination of conservative grazing and timber production can be carried out, as has been demonstrated in the longleaf slash pine forests (*19*, *38*) through the *judicious* use of fire to keep the forest open.

Plant Associations and Forage Species. The South is composed of three broad geographical regions: the Coastal Plains, the Piedmont Plateau, and the Mountain region. Of these, the Coastal Plains is the largest and most important for grazing.

Six fairly distinct plant associations compose the ecological land divisions of these three regions, namely: (1) wiregrass, (2) bluestem

(3) switch cane, (4) bottom land, (5) coastal prairie, and (6) marsh grass (*8*)

1 The wiregrass association comprises the most important cover for grazing in the Southeast It is essentially confined to the longleaf slash pine forest extending from South Carolina into Georgia, Florida, and Alabama Frequent burning has favored invasions of rather harsh but relatively nutritious, fire tolerant grasses From March to late June these wiregrass ranges are relied on for much of the grazing, but after June the forage is of low nutrition The more common grasses are pineland three awn (*Aristida stricta*), bluestems (*Andropogon* spp), panicums (*Panicum* spp), paspalums (*Paspalum*), Curtis dropseed (*Sporobolus curtissii*), cutover muhly (*Muhlenbergia expansa*), and carpet grass (*Axonopus affinis*) Grasses furnish 80 to 90 percent of the feed Palatable browse plants that occupy wet pine lands or swamps and are eaten generally in winter or spring, are (*3*) American cyrilla (*Cyrilla racemiflora*), bays (*Magnolia virginica, Persea pubescens,* and *Gordonia lasianthus*), black tupelo (*Nyssa sylvatica*), common sweetleaf (*Symplocos tinctoria*), groundsel tree (*Baccharis halmifolia*), laurel greenbrier (*Smilax laurifolia*), red maple (*Acer rubrum*), myrtle dahoon (*Ilex cassine* var *myrtifolia*), sumac (*Rhus copallina*), summersweet clethra (*Clethra alnifolia*), sourwood (*Oxydendrum arboreum*), sweetgum (*Liquidambar styraciflua*), tall gallberry (*Ilex coriacea*), and wax myrtles (*Myrica spp*) Gallberry (*Ilex glabra*) and palmetto (*Sabal spp*) are characteristic of this association but have no browse value

The more palatable forbs are cinnamon fern (*Osmunda cinnamomea*), common pokeberry (*Phytolacca americana*), nervein chainfern (*Woodwardia areolata*), pinebarren goldenrod (*Solidago fistulosa*), spotted ladysthumb (*Polygonum persicaria*), and whitetube stargrass (*Aletris farinosa*)

2 The bluestem association is dominated by bluestem grasses, but several of the grasses mentioned above intermingle These ranges furnish superior grazing from March 15 to early in May The forage is inferior during the hot weather in July but is fair in late August and September In fall and winter this feed is so inferior that the animals lose much weight unless supplements are provided

3 The switch cane association provides the best native range grazing in the South The dominant grass is switch cane (*Arundinaria tecta*) The heaviest yielding stands occur on untilled bottomlands of the Mississippi Delta and in large swamps in the Carolinas and eastern Virginia The grazing capacity varies from ½ to 2 acres per cow-month the best grazing period being from May to November

4 The bottom land cover, along the Mississippi and other rivers, supports a large variety of trees, vines, shrubs, grasses and sedges The better forage plants are the bluestems, carpet grass, switch cane, beak-rushes (*Rhynchospara* spp), sedges, greenbrier, and numerous hard wood sprouts Spring and summer is the best grazing season, but some of the browse plants provide good winter feed Conservative grazing is necessary to protect the hardwood-timber reproduction from injury

5 The true grassland (coastal prairie) association is found in southern Florida, southern Louisiana, and southeastern Texas The principal forage plants are bluestems, Bermuda grass, carpet grass, maidencane (*Panicum hemitomon*), and various paspalums The grazing capacity is high and the season of use is mostly yearlong

6 The marsh grass association occupies the southern coastline on slightly lower ground than the bordering grassland Most of this area is fresh-water marsh, but a fringe of salt water marsh occurs along the southeastern and Gulf coasts Dominant plants are bulrushes (*Scirpus* spp), cat-tails (*Typha* spp), cordgrasses (*Spartina* spp), maiden-cane, and saltgrasses (*Distichlis* spp) The fresh marshes provide the best grazing

Poisonous Plants Of the large number of stock-poisoning plants the following appear to be among the most troublesome in North Carolina and over extensive areas in the South (*31*) black cherry (*Prunus serotina*), Carolina jessamine (*Gelsemium sempervirens*), common chokecherry (*Prunus virginiana*), crow poison (*Amianthium muscae toxicum*), lambkill kalmia (*Kalmia angustifolia*), mountain laurel (*Kalmia latifolia*), pine deathcamas (*Zigadenus densus*), spotted waterhemlock (*Cicuta maculata*), white snakeroot (*Eupatorium rugosum*), and yellow buckeye (*Aesculus octandra*)

Methods of controlling poison plant losses are discussed in Chapter 21

Management Suggestions Many range and livestock practices in the South, especially on the forested lands, can be vastly improved The more important of these are listed below (*3, 4, 6, 7, 8, 19, 38*)

1 Do not keep the cattle on seasonal range beyond the period of satisfactory feed conditions Overlong grazing on forest ranges results in severe loss in weight of the animals, high death losses, low calf crop, inferior calves, and deterioration of the range

2 Where possible, *form or join a community* cattleman's association Free grazing on open range of absentee ownership is unsatisfactory, because it involves herds of different ownership, breeds and ages, inferior bulls, and poor management In various instances active community cattle associations have obtained grazing rights on forest land, purchased good bulls and suitable fertilizers, provided for supplemental

feed, hired riders, and developed improvements essential to good livestock and range management.

3. Adapt the kind and class of stock to the character of the forage. Cows of a desirable local breed do well on forest ranges where abundant nutritious feed is available. But do not place the cattle on forest range too early in the season.

4. Do not turn more cattle out on the open range than the range can maintain in good flesh year after year. Overstocking will injure both timber reproduction and soil. Obtain the best possible distribution of the animals over the range by suitable fencing, water development, and salting. There is no excuse for overgrazing on fenced pasture.

5. Avoid unnecessary death losses from starvation and plant poisoning.

6. Develop permanent pasture on good land for grazing when feed on open forest range is poor, as in winter and the midsummer dry season.

7. Use fire conservatively. Rationally planned burning is a good practice on longleaf-slash pine forest as a silvicultural tool, in reducing fire hazard, and in improving the forage. Returns from these lands are usually greater, under good management, from grazing and growing timber than from either use alone.

Marketing Cattle

Regardless of location, a rancher of breeding stock must first decide at what age and in what finish he wants to market his cattle. His decision will largely depend on the range forage available and on the hay and grain on hand.

In general, the poundage of beef produced from a breeding herd is greatest where offspring are sold as yearlings. Unless overhead charges of running the breeding herd are lower than average, the cost of calves per pound at weaning time is higher than for yearlings. Also, profits are usually less where all the steers are marketed as two-year-olds than as yearlings. Although a ranch is generally best suited for producing a specific age class of cattle for market, the price of calves, yearlings, two-year-olds, feeders, and finished cattle in relation to total poundage of beef produced must be taken into account in any ranching operation (*14*).

Sorting of the cattle into classes according to weight and/or quality should be done regardless of whether they are sold on the ranch or elsewhere. A buyer will offer a price closer to actual worth if the cattle are sorted into uniform lots than if the group is mixed. The sale

should he made when the animals are in the best state of flesh that the ranch is capable of producing.

Time of marketing is determined much more by the amount and quality of the feed available than by prices. For example, where tame pasture is available, the cattle may be held there until fat; elsewhere they may be fed concentrates while fattening on the native forage; on some ranches the yearlings may be roughed through on the range forage, with some supplemental feeding, and marketed grass-fat on lush forage the following summer. Again, the sale of feeder cattle on western ranges may be delayed until midwestern farmers have harvested the corn crop and are in the market for feeders (Chapter 2).

Range-Sheep Husbandry

In North America both farm and range sheep are raised for two valuable products: lamb (or mutton) and wool. Where the ewes are primarily of the wool type they are commonly bred to mutton bucks in order to produce more desirable market lambs.

Range-Sheep Breeds

The sheep is one of the oldest domestic animals on record. Many breeds have heen developed, and the best of them serve their purpose well. Yet only slight improvement in yield and quality nf the wool or meat greatly increases the operator's profits; hence new hreeds make their appearance from time to time. Most of the older ones were developed in England, though Spain and France also made valuable breed contributions.

Sheep are commonly divided into three classes according to fineness of the wool. The breeds used most extensively on range and farm pastures of the world (25) are listed below.

Fine-Wool	*Medium-Wool*	*Coarse-Wool*
Merino (*Spanish*)	Cheviot	*Cotswold*
Merino (*American*) *A*, *B*, and C types	Dorset Horn	*Leicester*
Delaine Merino (C type)	Hampshire[1]	*Lincoln*
Rambouillet	Oxford	Romney Marsh
	Shropshire	
	Southdown	
	Suffolk	
	Tunis	

In addition to these old breeds, there are a few relatively young breeds, mostly of the medium-wool, dual-purpose (meat-and-wool)

[1] This breed, along with the Oxford, Shropshire, Southdown, and Suffolk, are referred to as the "down" breeds, because they were developed in the hilly or "down" country of southern England.

type. Among these are the Corriedale, developed in New Zealand, a cross between the Merino ram and the Lincoln ewe. The Corriedale has a long staple of medium wool and is a good mutton type. In western United States, the Columbia and the Targhee breeds are being perfected from crosses between the Lincoln ram and the Rambouillet ewe. The wool grades as medium and the meat is of superior quality. Two additional crosses of less well-known characteristics are the Romeldale, of Romney Marsh ram × Rambouillet ewe parentage; and the Panama, of Lincoln ram × Rambouillet ewe ancestry. Additional crosses are being studied.

In the early years of American sheep raising, wool breeds were raised almost exclusively, because wool was in strong demand and could be marketed more easily than mutton. Thus the small, heavy-fleeced early type Merino, of Spanish origin, predominated. Later, the Rambouillet, a dual-purpose breed, which was developed in France from Merino parentage, gained an important place in America, especially on the western range. Today as formerly, these two breeds outnumber all others combined in the West.

The American Merino is an improvement over the original Spanish Merino. It is divided into types *A*, *B*, and *C*. Type *C* is the most popular, since it is the largest and has the smoothest skin. Although the Merino is not now raised to the extent it was 50 to 75 years ago, Merino blood is more prevalent in America today than that of any other breed. On the range the Merino does better than most other breeds where food is scanty; its dense fleece gives adequate protection from severe weather, and it produces a good wool clip; also, these animals, being gregarious, band together well and are easily handled. The carcass of the type *C* Merino rates as fairly good to good.

The Rambouillet is larger than the Merino; and, since it inherited the characteristics of the Merino parentage in the way of capacity to travel, hardiness, and the trait of banding together, it is the most popular breed today on the open range. The fleece is heavy and fine, and the carcass rates as good to excellent.

Crossbreeding

Crossbreeding of sheep in the West is practiced most where the ewes are predominantly of the Rambouillet or Merino breed and where the market demands larger lambs. The ewes are commonly bred to Hampshire or Rambouillet bucks or, in some localities, to Shropshire, Lincoln, or Suffolk sires. All crossbred lambs are sold. To provide good replacement stock, about a fifth of the better fine-wool ewes are mated with superior bucks of the same breed. Some operators prefer to

crossbreed all of the ewes sell them when they become old and purchase an entirely new young breeding herd If the band is to be enlarged by keeping all the good ewe lambs purebred bucks of the same breed should be used consistently

Breeding Season Mating Time and Percent Lamb Crop

Breeding Season. The building up of good grade ranch sheep is much like that described for cattle Well grown thrifty young ewes, preferably yearlings or 2 year olds should be selected for breeding herd replacements In advance of the breeding season the operator should check the age of the older ewes by examining their teeth and he should discard those having spoiled udders Range ewes should ordinarily not be kept or selected for breeding after reaching 6 years of age By then their teeth have worn down and have begun to spread and they graze less efficiently

The ram should be purebred and a typical individual of the breed He should preferably be a yearling or a 2 year old A young vigorous buck can be expected to serve from 45 to 65 (2 rams per 100) ewes in a breeding season of 60 to 75 days (26)

Mating Time The natural mating season of sheep is in the autumn The raising of so called hothouse or winter lambs as in parts of California and the southern states requires the use of certain breeds such as the Dorset Horn, Merino or Rambouillet, which will breed early in June or in July The gestation period averages about 147 days (21 weeks) and the time of placing the rams with the ewes is gauged to the preferred time of lambing

Size of the lamb crop is determined by the condition of the ewes at breeding time as well as thereafter Flushing the ewes that is placing them on green feed a short time before and during the breeding season is an excellent practice since it shortens the mating season and results in a larger number of twin lambs

Percent Lamb Crop Profits from sheep depend directly on the percentage of lambs dropped or raised The percentage of lamb crop varies greatly over the western range It probably averages around 75 percent (36) yet the best range operators may obtain 125 percent or more lambs and have a 100 percent crop at weaning time Management efficiency during the mating season, as well as afterwards, is clearly reflected in the percentage of lambs dropped and saved

Herding Methods and Use of Bedgrounds

The care of sheep on the open range differs from that of cattle in that a herder is on hand at all times This makes guidance of the band

possible over the range from day to day and gives protection of the animals by night. Only in the Midwest and East, and in a few localities in the West and Southwest where a coyote-proof fence encloses the grazing grounds, are sheep raised without the vigil of a herder.

The herder has heavy responsibilities. The average size of open-range breeding herds, as on the national forests, is from 1000 to 1400 ewes in addition to their lambs. Generally, the lambs in a band of more than about 1200 ewes do not make the most rapid growth; larger bands are also harder on the growing forage. However, if the band is composed of wethers or dry sheep, as on the winter range, one herder can care for a band of 2000 to 3000 head.

Quiet Handling and Open Herding. Sheep need guidance as they leave the bedground in the morning, some direction to suitable feed during the day, and lazy herding towards the bedground late in the afternoon. The experienced herder studies the range and plans the daily movements of the band well in advance.

It is essential, in the interest of both sheep and range, that the animals be handled quietly and with minimum use of dogs. Open herding, as opposed to close or "bunched up" herding, is a cardinal principle in range-sheep husbandry. Study of gains and wool clip of sheep grazed undisturbed on range enclosed by coyote-proof fence showed convincingly the importance of open herding of sheep on unfenced range, thereby allowing the animals to move about with minimum guidance so they can select the forage of their choice. Moreover, the acreage requirement was measurably less where open herding was employed (*17*).

Selection and Use of Bedgrounds. A bedground is an area upon which sheep (or goats) are permitted to congregate and rest for the night. The ideal bedground should be open, but it need not be free from brush or timber. It should be large enough for the band to bed down without crowding. It should be on higher ground than the surrounding country and should preferably be located at least ¼ or ½ mile away from a watering place.

Several-Night Camp. *vs.* One-Night Bedding-Out System. The oldest method is that of selecting a bedground more or less in the center of a range unit. Here sheep are bedded down several nights in succession before moving to another established camp, usually not until the forage within a distance of 1½ to 3 miles from the bedground has been consumed. Accordingly, in a short time the sheep must travel a considerable distance each morning before reaching fresh forage. This excessive travel to and from camp results in destruction of much vegetation (*11, 18*). Also, the hungry animals en route to the remote feed

often consume toxic or lethal quantities of poisonous plants. Because of convenience of location, this same bedground is usually used in subsequent seasons, hence the range becomes progressively depleted (*29*), and the operator's profits are correspondingly decreased.

Under the one-night bedding-out or "blanket" system the sheep are bedded down on new ground each night. The range close to the camp is not cropped down closely but is left in vigorous condition and may be grazed moderately again later in the season (*11*). Since the sheep are always on fresh feed, they graze during the cool morning and evening hours without traveling excessively, and they shade-up during the warmer daylight period. As they leave the bedground in the morning, they spread out in all directions and soon break up into small bunches if not checked. The conscientious, energetic herder will move around the outside of the band to turn back or retard the leaders. He will use dogs limitedly and will leave the sheep widely scattered to choose their forage as they go about in a leisurely way. The sheep are quietly brought together towards evening and bedded down on a suitable site wherever night overtakes them.

The one-night bedding-out system obtains the heaviest lambs and best wool clip from open-range grazing. By this system the sheep behave much as they do on fenced pasture, where they graze openly and quietly and do little trailing (*11, 18*). Since it is not economically feasible to fence the enormous acreage of public range and certain other large grazing areas, the one-night bedding-out system is recommended.

This bedding-out system will not be used by herders who lack energy, they avoid the work of breaking camp too often. Where the one night camp system is used the herder either carries his equipment, or he has a horse, or preferably a burro, that carries the tent (a light tepee), bed, and provisions to the new bedding ground. The trusty burro will graze with the sheep and will come to the camp site by night for a handful of grain. Although the herder must forego some comforts and conveniences of the several night camp system, conservation of the range and the additional gains of the animals clearly favor the one night camp system. The U S Forest Service, recognizing these advantages, does not now permit the use of a bedding ground for more than 3 nights in succession, except during kidding or lambing.

Salt and Salting. An adequate supply of salt for sheep is essential to their well being, also, it makes for easier herding. Salting is sometimes done every night, or on alternate nights on the bedground, or on a suitable site on the open range or in a corral at intervals of 3 to 7 days.

If salting is done on the bedground, no more is put out than the animals will consume in any one night, lest it be wasted. Bedground salting is offered to the animals in portable canvas or wooden troughs; or a few handfuls of granulated salt may be placed on grassy spots, rocks, or hard ground. If portable troughs are used, each about 3 feet long, three are sufficient for a band of 1000 ewes and their lambs, since only a part of the sheep will eat salt each night.

Of the granulated or crushed salt, a sheep will consume about ½ pound of salt per month on succulent feed and somewhat less on dry forage. Slightly more should be provided to offset wastage during rainy weather. Rock or block salt is objectionable, because sheep are likely to break their teeth on such "hard" salt.

Range-Goat Husbandry

Goats reared on the western range are of the Angora breed rather than of the milk breeds. Angoras are raised for two commodities: mohair and meat, called chevon. Another reason why some ranchers keep a few goats is to suppress or destroy brush.

Goat raising as a specialty is usually confined to ranges having the kind of browse that can be utilized more efficiently by these animals than by other stock. In 1946, the seven leading goat-raising states, in the order named, were: Texas, Arizona, New Mexico, Missouri, Oregon, California, and Utah *(32)*.

Management Considerations on Open Range

Profits from goat herds and range condition are both directly affected by the way the animals are handled and the suitability of the feed.

Desirable Goat Range. The suitability of range for goats depends to some extent on the climate, but chiefly on the forage. Regions of mild winters, reasonably dry atmosphere, and an altitude of from 1000 to 2500 feet are especially adapted to goats *(40)*.

The ideal range should provide forage suitable for goats at all times of the year. It should be well drained and free from prolonged heavy rains; it should have adequate water, well distributed; and several desirable sites for bedding grounds.

Abundant suitable browse is an essential requirement for goats. Although they feed upon a variety of plants in spring and summer, including tender grasses and forbs, browse composes much of their diet at all seasons *(35, 40)*. In winter, when grasses and forbs are less palatable or covered by snow, goats subsist almost exclusively upon browse. Deciduous brush species rank highest as feed during summer

and fall, and nondeciduous (evergreen) forms are primarily important in winter.

Most woody plants of the United States are browsed by goats to some extent. In the West, the following are among the more important (*9*): Apache plume (*Fallugia paradoxa*), aspen (*Populus tremuloides*), bitterbrush (*Purshia tridentata*),*[2] deerbrush (*Ceanothus integerrimus*),* Fendler ceanothus (*C. fendleri*),* wedgeleaf ceanothus (*C. cuneatus*),* cherry (*Prunus* spp.), cliff rose (*Cowania stansburiana*),* junipers (*Juniperus* spp.),* maples (*Acer* spp.), manzanitas (*Manzanita* spp.), New Mexico locust (*Robinia neomexicana*), oaks (*Quercus* spp.), roses (*Rosa* spp.),* sagebrush (*Artemisia* spp.), serviceberry (*Amelanchier* spp.),* silktassels (*Garrya* spp.), snowberry (*Symphoricarpos* spp.), sumacs (*Rhus* spp.), and willows (*Salix* spp.).*

Poisonous Plants. Little specific information is available concerning losses of goats from eating poisonous plants. The popular belief that goats can live and thrive on any feed is not true. Chapline (*9*) concluded that several plant species that are poisonous to cattle and sheep also cause losses among goats.

According to Marsh (*24*), the following plants are responsible for most losses among goats from poisoning on the western range: coyotillo (*Karwinskia humboldtiana*), crazyweed (*Oxytropis lambertii*), locos (*Astragalus* spp.), and poison bean (*Daubentonia drummondii*). These plants are common in the southwest where goats are raised most extensively.

Control of goat losses from poisoning lies in the field of prevention rather than cure, as discussed in Chapter 21.

Herding and Use of Bedgrounds. Small goat herds are generally grazed on fenced pasture. Under such circumstances goats, like sheep, graze singly or in small groups and bed down where night overtakes them. Under open range grazing, handling of the herd, which should not exceed about 1200 mature animals, entails many problems similar to that described for sheep. Goats should be grazed quietly and openly, the herder should be in front of the band to turn back or slow down the leaders, and he should use dogs limitedly to prevent the animals from bunching.

The too common practice of bedding goats in a corral at the ranch headquarters should be discontinued. Although the one-night bedding-out camp system is ideal, it is less commonly employed for goats than for sheep. The next best practice is to use several bedgrounds, each for not more than 3 or 4 nights in succession, so the animals are near fresh feed each morning.

[2] Species that are highly palatable to goats are indicated by an asterisk.

Salt and Salting. Goats, like sheep, are more easily handled and thrive best when salted amply, regularly, and at frequent intervals. Granulated or crushed salt may be fed each night in small quantities on the bedground, or in larger amounts every 5 to 7 days on bedground or on range. The salt may be placed in boxes or troughs, on flat rocks, firm ground, or in portable canvas troughs (*9*).

Goats will eat 3½ to 4 pounds of salt per animal per year. They consume a larger amount while on succulent feed than on mature forage.

Breeding Season and Care of Kids

The successful producer gives much thought and attention to the breeding of his goat herd and to the care and management of the young kids. By selecting good, purebred bucks and by proper annual culling of undesirable does, the herd will respond unmistakably to nature's laws and make for a more profitable enterprise.

Mating Season. Does seldom come into heat until late summer, fall, or early winter. Since the gestation period varies from 147 to 155 days, the bucks are usually turned in with the does in October and November so that kidding comes in March and April.

The bucks should be purebred Angoras and preferably long yearlings of good vigor. A ratio of 1 buck to each 40 or 50 does is satisfactory for a mating season of about 45 days. The herd should be on succulent, nutritious forage a few weeks before and during the breeding season.

The Kid Crop. The percentage of kids raised is a big factor in determining profits. The highest percentage of kids is generally obtained where the toggle or staking system is used, preferably combined with the employment of individual claiming pens for does that disown their kids. In using the toggle system the individual kids are staked some 10 feet apart. The rope is about 15 inches long and has a swivel and leather loop fastened to the kid's fetlock joint. Each kid should have a simple shelter for protection from strong sunshine or rain. The does are taken out to graze early in the morning and brought back about 11 A.M. They are again moved to the grazing grounds in the afternoon and are returned to the camp for the night. Kids born at headquarters are toggled with minimum delay, and those dropped on the range are brought in with the does for toggling. The kids are kept toggled for 10 days or so, or until strong enough to follow the does to the range.

Some operators prefer the pen system exclusively, since it entails less work than toggling and usually results in a good kid crop. In this system the does and kids, when the kids are strong, are transferred

from the individual pens to small community pens where kids of about the same age are grouped together In the morning the does are sent out to graze and are sorted through a chute into their respective pens in the evening In a few days the does and kids are transferred to the larger 'mixing pens When 10 to 15 days old the kids are placed in a still larger pen and are finally permitted to follow the does to the range

Brush Clearing By Goats

Since goats feed extensively upon woody plants they are often employed for thinning out or clearing brushy areas Grasses and forbs occupy the ground as the brush gives way, thus making the area more suitable for grazing by other kinds of livestock

Goats are most effective in destroying brush after a fire has been run through it Brush or tree species that sprout provide relished food for goats, and the seedlings are also cropped back Goats are most effective when confined by a fence and kept on the area yearlong To destroy dense stands of sprouting brush 2 or 3 goats may be grazed per acre the first year, and the number is decreased as the browse is thinned out Some operators prefer to divide the pasture into two equal parts and to rotate the grazing from one unit to the other every third week as the sprouts revive By this method land can be cleared in 2 to 3 years A fairly good profit can usually be realized from Angoras while they are destroying the brush

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Chapter 16

RANGE CONDITION AND TREND AS GUIDES TO BETTER MANAGEMENT

The theme around which this chapter is built is that "moderate grazing pays." If decline in grazing capacity is recognized early and the adverse factors are corrected, most ranges will soon regain their productivity. But, if the depletion is far advanced, radical management adjustments must be made and recovery will be slow and costly.

In recent years research workers have set up guides to assist stockmen and land administrators in recognizing various degrees of range depletion—termed "range condition"—and in noting departures in the botanical composition of their ranges—referred to as "trend"—or successional changes in the vegetation.

In this chapter range condition and trend are defined, the history of and reasons for decline of the western range are considered, and methods of rating range condition and ways to use these ratings to improve and maintain a desirable range cover are outlined.

Range Condition and Trend Defined

Range condition and range trend are intimately associated, for one is a reflection of the other.

Range Condition

The popular usage of the term "range condition" refers to the forage production of the current year, season, or month as compared with that of the last or some other year.

Since climate may greatly influence forage production, the term *climatic condition approach* has been suggested for popular condition classification (23). The monthly climatic and summary reports compiled by the Bureau of Agricultural Economics for the range-livestock states supply the data for these reports. Favorable current climatic factors account for excellent-to-good range condition, unfavorable

growth seasons for fair-to-poor condition The climatic approach does not consider forage composition, amount of mulch on the ground surface, erosion, or the potential grazing capacity of the area Although the popular condition approach is useful in indicating the current volume of herbage, it does not reflect needed correction for a declining range

The technical usage of range condition as employed by range conservationists refers to the response of forage cover and soil to the grazing practice in operation taking into account also current climatic conditions It is defined as the *state of health* of a specific range area and is expressed in the amount of forage that an area will produce under the best practical management (*8*)

Condition broadly depicts for specific range units the character, amount, and stability of the forage crop and the amount and quality of livestock products that each should produce Ranges in excellent condition[1] yield maximum returns, but, unless kept so, production will decline and cost of operation will rise Excellent-condition ranges have a stable productive soil, at least a thin layer of decaying vegetable material between plant tufts, and usually a dominance of climax or subclimax vegetation Dyksterhuis (*12*) defines range condition as 'the percentage of the present vegetation which is original vegetation for the site' Accordingly, condition of a range unit reflects the combined effects of its history, past and present usage, climate soil, and vegetation

History of Decline of the Western Range

On all continents the *grazing capacity* has declined perceptibly and the less desirable forage plants have markedly replaced the better ones. The most severely punished tracts occur in the older low-rainfall countries where unwise grazing has been practiced longest and where periodic droughts have hastened the effects of excessive grazing (*32*). Portions of North and South Africa, Greece, Spain, India, and Palestine are outstanding examples of grassland devastation. In the younger nations, Australia, New Zealand, and western United States, few tracts can now match the yield and forage quality they produced in their virgin state.

The history of range decline is well illustrated in western United States. The transformations have been summarized as follows (*36*):

> When the white man first placed his animals on the western range the forage crop seemed inexhaustible. Probably a vegetal resource was never exploited more rapidly, for wild tales of quick profits lured thousands of stockmen to send their animals to the West. Soon the ranges were stocked far in excess of their carrying capacity. Within half a century or less of uncontrolled grazing the ranges became seriously impoverished. Bartlett (*2*), in 1854, glowingly described the productive grasslands of Texas and the adjoining territory. But soon after the coming of the railroad, in 1883, these lands were overrun with livestock, and within a few years extensive grass stands yielded to mesquite bush and prickly pear (*3*). In California as early as 1865 General Bidwell (*4*) recognized that the indigenous grasses, once so abundant, were fast disappearing from the plains.
>
> In 1939, the Forest Service (*45*) estimated that the reduction in carrying capacity of the now existing western range was 52 percent below its virgin condition. On some 55 percent of the entire range area, forage resources had been reduced by *more than half*. Various choice perennial bunchgrasses and highly palatable shrubs had disappeared largely or completely on some ranges, and their place was taken by such unpalatable plants as sagebrush (*Artemisia* spp.) and exotic weedy species such as downy chess (*Bromus tectorum*), star thistle (*Centaurea* spp.), and Russian thistle (*Salsola pestifer*).

Although many of the earlier range-land abuses have been corrected, progress in adopting better management and improved range condition has been slow.

Soon after the public lands, notably the national forests, came under control, administrative studies showed particular need for: (1) placing the kind of stock on the ranges in accordance with the character of the forage, the nature of the topography, and the availability of water, (2) adjusting livestock numbers to the carrying capacity of the range, (3) obtaining more uniform grazing through better livestock distribution, (4) delaying spring grazing until the forage has made adequate growth, and (5) less close grazing generally and deferred-rotation grazing of critical areas.

In the absence of experimental background to show what constitutes suitable grazing seasons, proper range use, and trends in range condition, pioneer stockmen and range administrators attempted to adjust the degree of cropping by ocular estimates of what they believed to be safe grazing use. In recent years the Soil Conservation Service has been particularly effective in giving cooperating ranchers advice and technical assistance in matters of sound range conservation practices (Chapter 24). Despite these efforts, grazing capacity continued to decline, reflecting the dire need of further range-land research and extension work.

Development of Range Condition Concept

The general ideas of how to recognize range conditions are exceedingly old. The theme of grazing and of adequate, productive fields of grass for the cattle carries all through Genesis and Exodus (*19*).

On the western range the earliest investigators recommended that stocking be such as to "improve the condition of the range." The more outstanding pioneer workers were Vasey (*48*), Smith (*38*), Bentley (*3*), Griffith (*15*), and Thornber (*44*), whose findings were reported between 1888 and 1910. However, the range-use planning and improvement programs of today had to await subsequent researches and the synthesis of these findings.

In 1936, Tallmt and Crafts (*43*) pointed out the need for some simple means of differentiating between range areas in various stages of depletion. In 1938 Spence (*39*), wishing to give an ecological expression to the effects of grazing, proposed the term "range condition." Among subsequent contributions the works of Renner and Johnson (*33*), Costello and Turner (*10*), Humphrey (*21*), and Pickford and Reid (*29, 30*) were particularly helpful in showing how to recognize range-condition classes and how these classes could be applied in practical management. In the meantime numerous reports on the subject have been published for local use, especially by the Soil Conservation Service (*16, 23, 24, 25, 50*).

Although the classifications proposed differ somewhat according to climatic regions and plant associations, they were mostly built around the concept of trends in the succession of the range plant cover. According to Dyksterhuis (*12*):

> Since the description [of range condition] usually shows a different floristic, or species composition for each condition class . . . it is concluded that the concept of range condition classes dates back to research by Sampson (*34, 35*).
>
> Sampson's researches published in 1919 after 13 years of study in

western United States, contains the conclusion "that the most rational and reliable way to detect overgrazing is to recognize the replacement of one type of plant cover by another." Equally important was his conclusion—"the grazing value of the vegetative covers is essentially determined by the stage of succession. Locally, and indeed generally, the carrying capacity and forage value are the highest where the cover represents a stage in close proximity to the herbaceous climax and lowest in the type most remote from the climax." This was application of the Clementsian[2] concept of plant succession and climax to practical range problems (Fig. 75). Later researches (*5*, *6*, *11*, *30*, *31*) covering both plant production and succession showed differences in methods, as in locale, but served to confirm Sampson's (*35*) conclusions . . The "stage" concept of range degeneration of Sampson (*35*) meanwhile had been transformed into range condition classes. Humphrey (*22*) traced early development of the use of range condition classes in forage surveys. He also presented one method of determining range condition. There are now many ways of determining, as well as of applying, range condition classes. This is true of classifications that do not depend upon position of the vegetation in the scale of secondary succession. For example, one view is that range condition may be measured directly in terms of forage production. However, ecologic research shows that forage production is generally only a reflection of range condition. Also, that range recovery is accomplished through secondary succession (*9*).

According to Renner (*32*):

> Although there are some exceptions, generally speaking, the high producing forage species are components of the climax vegetation. They usually provide the best possible protection to the soil, the greatest variety and quantity of forage, the highest grazing capacity, and the greatest production of livestock products.

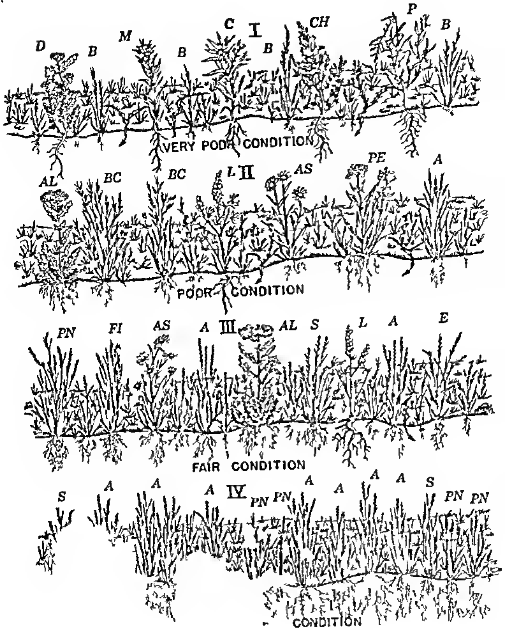
Reasons for Decline in Range Condition

Three factors frequently account for the decline of range condition: too close and/or unseasonable grazing; invasions of woody plants; and abnormal climatic conditions (*17*). The first factor is subject to direct control by the operator; the influence of the other two can be minimized by adopting tested management practices.

Too Close Grazing

Grazing beyond the endurance of the forage cover is the most widespread single cause of decline in range condition. Too close and espe-

[2] The late Dr. F. E. Clements, deservedly called the "father of American plant ecology," traced the sequences in plant succession in western United States (7). His studies helped formulate range-condition classes and advanced techniques useful in range research.


D B M B C I B CH P B
VERY POOR CONDITION
AL BC BC L II AS PE A
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CONDITION

cially too early spring cropping adversely affects forage yield, plant composition or trend, and adequacy of mulch, and it promotes soil erosion. A range long overgrazed has usually lost a large proportion of its best forage plants. This is commonly accompanied by increase in unpalatable or even poisonous plants, and by lower animal production.

Any development toward a better quality of forage is associated with increased vigor of the highly palatable plants. Ample, high-quality forage is the first essential in profitable range-livestock management.

Range condition is intimately bound up with the closeness and season of grazing. This relationship has helped develop a technique of measuring the degree of grazing. "Utilization," as this technique is called, is the extent to which grazing animals have cropped the current growth within their reach (Chapter 17). Utilization may be expressed in percentage of height or weight of forage removed, or in such general terms as excessive, close, moderate, or light when dealing with an entire range unit.

Periodic checking of the degree of utilization, such as at the mid-grazing season, will reveal which of the forage plants is most palatable and desirable and also whether the condition of the range is likely to be lowered should all animals be kept on the area until the end of the normal grazing season. The concept *that current range utilization should not be used as a criterion of range condition* is not always true. A single season of too heavy grazing results in a smaller amount of decomposing *vegetation to protect the soil against erosion* and in lowered range condition. When range condition is used to correct management practice degree and season of use are always considered, but certain other causes of depletion are often overlooked.

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brome (*Bromus carinatus*), *L*, lupine (*Lupinus alpestris*). *AS*, (*Aster frondens*), *PF*, penstemon (*Pentstemon procerus*), *A*, slender wheatgrass (*Agropyron trachycaulum*). Perennial forbs of low palatability predominate. Mulch occurs over only portions of the soil surface, and soil erosion is generally severe.

III. Fair range condition. *PN*, Nevada bluegrass (*Poa nevadensis*), *II*, Idaho fescue (*Festuca idahoensis*). *AS*, aster, *A*, slender wheatgrass, *AL*, yarrow, *S* subalpine needlegrass (*Stipa columbiana*), *L*, lupine, *F*, blue wild rye (*Elymus glaucus*). Grasses are abundant and are reproducing, but there are several weeds of low palatability. There is a small amount of litter over most of the ground surface, and current soil *erosion is moderate*.

IV. Good to excellent condition. *S*, subalpine needlegrass, *A*, slender wheatgrass, *PN*, Nevada bluegrass. *The grass stand is perennial, vigorous and dense,* and reproduction is satisfactory. Mulch covers the ground surface, there is little or no *noticeable current erosion,* and gullies have healed.

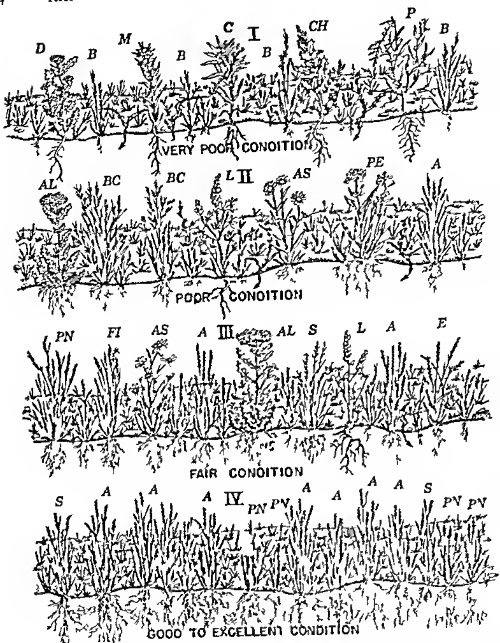


FIG 75 Successional trends of range lands in the mountains of Utah representing indicator plants typical of areas in different condition stages

I Very poor range condition (left to right) *D* tansy mustard (*Descurainia richardsonii* var *incisa*) *B* nodding brome (*Bromus anomalus*) *M* tarweed (*Madia glomerata*) *C* collomia (*Collomia linearis*) *CH* lamb s quarters (*Chenopodium album*) *P*, Douglas knotweed (*Polygonum douglasii*) Note the sparse growth and predominance of taprooted annuals There is but a trace of mulch, current soil erosion is severe and new gullies are forming

II Poor range condition *AL* yarrow (*Achillea lanulosa*) *BC*, mountain

that the acreage of each class and the potential capacity are the same and that the season of grazing is identical

Excellent Condition Range producing from 75 to 100 percent of potential capacity of the area and composed largely of the choicest forage plants, mostly high in succession sequence The forage stand is vigorous and all species are reproducing well, there is a mulch layer in openings and between plant tufts, the soil is loose and friable, and soil movement and runoff are no greater than on ungrazed areas This range will support, without deterioration, 100 cattle for the established grazing season

Good Condition Range producing from 50 to 75 percent of potential capacity Although the better perennial forage plants predominate, the stand contains many less desirable perennial forbs of the subclimax stages Whereas the forage stand is vigorous and producing an abundance of viable seeds, fewer seedlings are becoming established than on range in excellent condition A few bare spots are showing up, there is less mulch on the ground, and some soil washing is taking place No more than 75 cattle can be grazed if further decline in range condition is to be avoided

Fair Condition Range producing from 25 to 50 percent of potential capacity The cover consists of early maturing medial successional stage plants of low value for livestock and as soil binders Undesirable woody plants may be appearing The highly palatable perennial grasses are too weak to produce much seed, and reproduction from rhizomes is limited The surface soil has a 'baked' appearance, there are many bare spots, new gullies are forming, and the runoff carries much silt Not more than about 50 cattle can be pastured during the established grazing season

Poor to Very Poor Condition Range producing no more than about 20 percent of its potential capacity (poor), or less than 25 percent (very poor) Poor or very poor range condition yields a sparse and unstable forage, little mulch, and it offers only weak resistance to runoff and erosion The cover is largely composed of unpalatable forbs and shrubs The better forage plants occur mainly under bushes and in other protected places Not more than about 25 to 35 cattle can be pastured during the normal grazing season, and they are likely to be in poor flesh

Mulch and Range Condition

'Mulch' and 'litter' are dead plant material on the soil surface Since litter is used to express undecomposed forest floor materials this term may cause confusion when applied to the residue of grasslands

Invasions of Woody Plants

In many regions of the West invasions of less desirable or wholly unwanted woody growth has crowded out much of the desirable herbaceous forage cover. In the Southwest and southern Great Plains burroweed, creosote bush, mesquite, scrub oak, and others have in many instances within the memory of the land owner greatly lowered the grazing capacity of large areas. In the foothills of California invasion of ceanothus, chamise, manzanita, oaks, and digger pine is a normal successional phenomenon. In the Great Basin and adjacent regions species of sagebrush have materially reduced the range forage. Studies of how to control these invaders are under way in practically all pasture regions of the United States (Chapter 13).

Abnormal Climatic Conditions

The vicissitudes of climate—cycles of drought alternating with periods of normal rainfall—are conspicuously reflected in the forage yield, especially in the arid West. Cycles of dry and wet years in some regions form a reasonably predictable pattern. In the Southwest, for example, rainfall well below normal tends to occur every 3 to 5 years. During a 3-year drought in Arizona the density of black grama (*Bouteloua eriopoda*), a perennial, on ungrazed plots declined 48.5 percent and conspicuously more on heavily grazed plots (*26*).

Climate alone markedly influences forage yield and range condition, and the combined effect of climate and too close grazing may quickly transform a range unit from excellent to low condition. To be safe, managers and producers should calculate the animal months grazing of their range in years receiving slightly less than normal rainfall.

Classification of Range Condition

Livestock operators and administrators will be aided in recognizing trends in the cover and stability of the soil of their holdings if they will sketch broadly on a map the boundaries of the different condition classes. The classes are kept broad to facilitate their use in correcting faulty grazing practices.

Range Condition Classes

Four range condition classes are commonly employed: excellent, good, fair, and poor. The descriptions for these classes apply particularly to grass and forb ranges but may be adapted to areas of mixed covers such as browse and grass. For purposes of comparing grazing capacity of the condition ranges described below, it is assumed

yielding, often heavily trampled, and usually closely cropped—show little or no *A*-soil horizon The poor condition units are difficult to improve, for they are low in both mulch and humic mulch, and the soil is compacted and exposed Wall barley occupies dark, springy soils with abundant humic mulch and produces a large amount of moderately palatable forage Soft chess and wild oat occupy intermediate sites, less mulch is left on the ground, since their herbage is highly palatable, though less so than the filaree

TABLE 20

MULCH ON THE GROUND, CALIFORNIA

Dominant Species	*Excellent*	*Good*	*Fair*	*Poor to Very Poor*
Redstem filaree (*Erodium cicutarium*)	200+	100–200	50–100	50 or less
Soft cheat (*Bromus mollis*)	250+	150–250	100–150	100 or less
Wild oat (*Avena fatua*)	200+	150–200	100–150	100 or less
Wall barley (*Hordeum leporinum*)	1500+	1000–1500	500–1000	300–500

Only limited measurements of mulch have been made on perennial bunchgrass and sodgrass ranges In relatively heavy rainfall regions the poundage of mulch and humic mulch on areas in excellent condition may exceed that of the current forage yield (*14*), in regions of moderate rainfall it may vary from about one third to one fifth of the season s forage growth, in semiarid regions from around 100 pounds per acre on moderately good sites to a mere trace

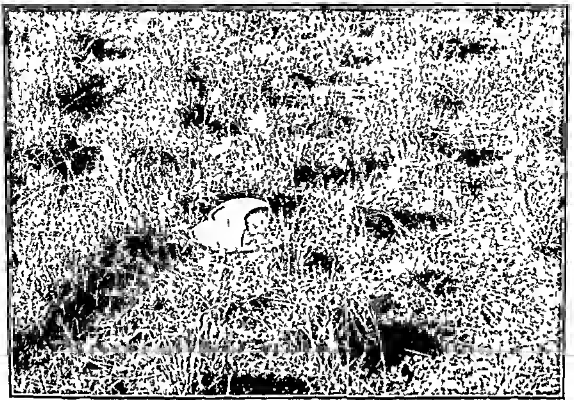
In general the amount of total mulch on the ground is expressed in *percentage of ground area covered between grass tufts*

Methods of Rating Range Condition

The method of rating range condition for a specific area is usually determined by the character of the vegetation, familiarity of the worker with a given technique, and the accuracy needed The most extensively employed methods are (1) quantitative climax approach, (2) palatability rating approach (annual ranges), (3) range-potential approach, (4) scorecard approach and (5) three step approach

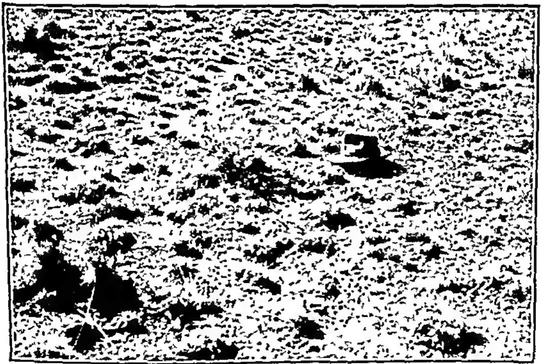
QUANTITATIVE CLIMAX APPROACH

This approach applies strictly to perennial grasslands As reported by Dyksterhuis (*12*), it is based on the percentage of present vegetation in the stand that was part of the climax Measurement is made by noting the relative abundance of 'decreasers increasers and invaders' All range plants belong to one of these groups Most of the



(Courtesy of U. S. Soil Conservation Service, 10046)

FIG. 76. An area in Oregon of bluebunch wheatgrass (*Agropyron spicatum*), showing conservative grazing and good-to-excellent range condition. Stubble height averages about 6 inches. The numerous seed stalks connote abundant seed production.



(Courtesy of U. S. Soil Conservation Service, 10033)

FIG. 77. Same association as in Fig. 76, showing far too close utilization and poor range condition. Many grass tufts have been killed, there are few seed stalks and practically no seedlings. There is little mulch, and erosion has carried away much of the topsoil.

decreasers and many of the increasers are valuable forage plants and are abundant in stable or climax communities The invaders are mostly poor forage plants, commonly abundant on overgrazed unstable areas.

For convenience in field work the data recorded for the four range-condition classes are shown in Table 21

The total percentage of decreasers, increasers, and invaders is always 100 In practical field-condition classification, relative abundance of the three plant groups may be estimated to the nearest 5 percent. A table listing the more common and reliable decreasers, increasers, and invaders—and the percentage of these in each condition class—must be prepared for the distinctive range region, plant associations, and sites.

TABLE 21

RANGE-CONDITION CLASSES

Plant Group	*Excellent* (Relative Percentage)	*Good* (Relative Percentage)	*Fair* (Relative Percentage)	*Poor* (Relative Percentage)
Decreasers	55–80	35–55	10–30	0 0–10
Increasers	20–35	25–40	15–25	5–15
Invaders	0 0–10	10–45	45–75	75–100

Failure to take specifically into account the relative abundance of the decreasers, increasers, and invaders has proven unsatisfactory where both sodforming species and bunchgrasses compose the cover Schultz (37), in eastern Nebraska, found that decrease in percentage of vegetation, as measured by the decreasers, is first accompanied by increase of total vegetation in terms of basal cover or density Many of the increasers by reason of their sodforming habit and vigorous vegetative reproduction, fill in the interspaces between the bunchgrasses without apparent detriment to them. When too heavy grazing is prolonged to the point where the increasers begin to thin out, the decreasers drop rapidly out of the stand Comparisons made according to pounds of herbage produced per acre revealed that the decreasers yielded as much in the *good-* as in the *excellent*-condition class, in addition, the increasers contributed greatly to the yield, so that total production was greater in the lower stage of degeneration from the climax, hence the grazing capacity was not impaired In the locality studied yield by species indicated the goal for management more closely than did relative composition by species, notably in the early stages of range deterioration

On perennial grasslands of the West, including meadows, the climax grasses (Figs. 76 and 77) compose most of the cover on excellent to-good-condition ranges (*9, 10, 21, 30, 31*)

FIG 78 Annual range in excellent condition This area adjoins the one in Fig 79 but is less steep Abundant current growth has been left each season to protect the seedlings and maintain soil productivity The grazing capacity is high, and there are *few undesirable plants* Contra Costa County, *California* (Sept 10, 1948)

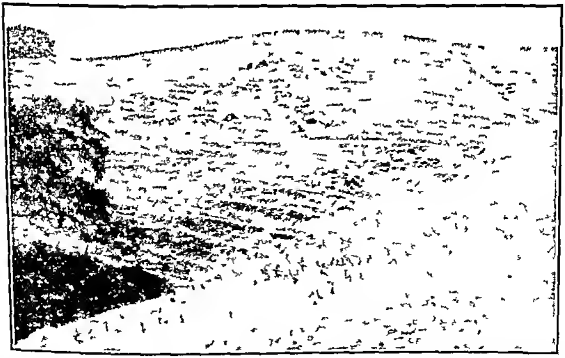


FIG 79 Annual range *in poor condition* An undesirable cover of annual vegetation that has been overgrazed by cattle from early spring when soil was wet through much of the summer after the forage had dried Note the numerous hillside trails and the presence of weeds in the foreground The grazing capacity is low (Sept 10, 1948)

Palatability-Rating Approach (Annual Ranges)

Rating of condition by this method places primary emphasis on the preference ratings by livestock of the plants composing the cover regardless of their successional sequence. A stand composed largely of palatable plants would receive a high-condition rating, one consisting mostly of unpalatable species would be rated low.

The palatability-rating approach is taken more or less for granted on such annual ranges as the foothills of California. Swift and Fausett (*41*) classed as in "satisfactory" condition units of annual California foothill lands that supported a large proportion of such highly preferred plants as soft chess (*Bromus mollis*), alfilaria (*Erodium* spp.), and wild oat (*Avena fatua*). Young (*50*) classed as excellent to good areas where bur-clover (*Medicago hispida*), alfilaria, soft chess, and scattered perennial grasses composed from 70 to 90 percent of the vegetation. Ranges in fair to poor condition were dominated by less desirable and undesirable range plants. Hormay (*20*) points out that annual ranges in excellent-to good condition produce a relatively thick, even, and vigorous stand of palatable forage (Fig. 78). The soil has a thin mulch with some decaying vegetation on the surface, and there is no active erosion. Poor condition annual ranges tend to produce a small, stunted cover containing many weedy plants, erosion is usually in evidence, and gullies are actively cutting into drainage channels (Fig. 79). These aspects reflect past use and indicate present condition.

Range Potential Approach

Classification of range units by this approach aims, according to Humphrey (22), to *express their current production in terms of their ultimate potential*. Such classification is primarily useful in recognizing and then setting up management plans that will bring individual range areas into their maximum productivity.

Potential approach assumes that (1) range condition is not a temporary state, (2) differences in forage production caused by detrimental climate do not necessitate reclassifying range condition annually, and (3) range in excellent or good condition will produce more desirable forage than when in fair or poor condition.

Recognition of the potential yield capacity involves consideration of all pertinent factors, especially forage composition and density, plant vigor, amount of mulch present, and degree of soil erosion. Plant composition is regarded as essential to condition classification, but density of cover has too frequently been ignored. A range that has only 0.2 density of highly desirable species but which could support

(3) checking the practicability and devising a means of measuring trends on range allotments, and (4) determining the place of photographs in recording condition and trend Coworkers of all U S Forest Service regions and stations agreed that in order to follow trends permanently located plots or transects must be established on representative areas of the allotments investigated

The Three Step Method incorporates the more desirable features of several quantitative methods *Step one* adapts the Australian point-observation method (Chapter 4) in which a ¾-inch wire loop is dropped at foot intervals along a tape to note presence and identity of vegetation and the proportion of ground surface covered by mulch Permanent stakes mark the transect location *Step two* employs the Southwestern Condition and Trend Score Card for noting additional essential facts *Step three* provides for taking two key photographs along the transect which record, in part, the elements observed and measured in the two previous steps The numerically expressed data are analyzed statistically The time required for taking the three sets of records is low for experienced men some 25 minutes for step one, 15 minutes for step two and 8 minutes for step three

No claim of adaptability or success in all grassland associations is made for the Three Step Method Since it appears promising, further study seems warranted

Improved Management, the Key to Better Range Condition

A knowledge of range condition will point the way to needed improvements in management and will familiarize the operator with the forage resources of his lands

Although there is no miraculous short cut or inexpensive way of bringing back a range unit from poor to excellent condition the best procedure is to coordinate the grazing use with the annual production of forage under existing conditions (*33*)

Season and intensity of grazing should be adjusted to favor the development of a plant cover and mulch adequate to protect the soil mantle, this measure should bring about reproduction of the higher successional or otherwise desirable forage plants Conservative stocking is essential to all improvement measures

In improving the range condition, the operator should consider the merits of (1) adopting a later or shorter grazing season, (2) obtaining better distribution of the livestock over the range, thereby minimizing spotty overgrazing and too light cropping elsewhere, (3) reseeding or applying deferred rotation grazing on areas in special need of revegetation, (4) placing division fences for better distribution of the animals

0.4 density has sometimes been classed as in excellent condition instead of fair, let us say, according to its potential production. On forest ranges, notably cutover lands, potential production may gradually change primarily because of plant competition, secondarily because of excessive grazing. Much of the restocking cutover ponderosa pine forests of the West, for example, have shown sharp decline in the density of perennial bunchgrasses (*1*). In many instances forest growth has extended into grassy glades and into meadows where the water table has dropped. The potential forage production of these areas remains unchanged, hence they must be classed as in poor condition regardless of whether it is uneconomical to remove the timber or brush.

Scorecard Approach

Classification by this means implies that the examiner after inspecting a range unit has answered on a special card or sheet the various important questions pertaining to condition outlined thereon. In the administration of Federal lands and other large acreages, the extent to which one can classify range condition is predicated on what can be done with limited funds and personnel. Sampling of condition, in general, must be confined to critical areas.

Confronted with this practical problem, Parker and Woodhead (*28*) developed the Southwestern Condition and Trend Score Card for grading condition and trend on perennial grassland ranges. The classification is based on numerical values empirically assigned to the following primary topics: (1) general health and vigor of the chief forage species, (2) density, composition, and the overall grazing value of the cover, (3) successional indicators, including annual grasses, weeds, and noxious plants, (4) soil indicators such as amount of mulch, general extent of soil removal, and degree of gully formation, (5) animal indicators, including weights made by the stock grazed and appraisal of the populations of rodents and rabbits. The summarized score of numerical values assigned to each heading automatically classifies the range into "excellent," "good," "fair," or "poor to very poor" condition.

Outlines similar to the score card have been employed by other workers (*21, 33, 42*).

The Three Step Method

Other approaches of range condition and trend may best be indicated by Parker's (27) Three Step Method.

Considered for administrative use on national forests, the method aims at: (1) developing a practical method for measuring trend, (2) considering the adequacy of present range-condition standards,

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along the outer boundaries of the different condition classes in order to graze lightly the portions where improvement is needed most, (5) herding the animals away from areas especially in need of improved condition, (6) placing salt and developing stock water on units in excellent or good condition, (7) avoiding close herding of sheep and goats or of camping overlong on conveniently located bedgrounds, and (8) obtaining better financial returns by grazing with the kind of stock best suited to utilize the range and considering whether more than one kind of stock should be grazed

In judging range condition it should be kept in mind that soil stabilization is of primary importance Areas where accelerated soil erosion is taking place are in unsatisfactory range condition On such areas soil stabilization should be regarded as primary and forage utilization as of secondary importance

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Chapter 17

RANGE UTILIZATION

Two questions confront all successful range- and farm-pasture operators in the harvesting of the yearly crop of forage: "How closely may a range area be grazed without damage to forage stand and soil?" and "How may one determine how closely a range unit has been grazed?" The knowledge available on the subject, though not final, can do much towards stabilizing the grazing industry.

Standards of Range Use

By definition, range-utilization standards—also termed "allowable" or "proper" range use—is a yardstick or indicator guide for judging the closeness of grazing allowable on a range area in the interest of livestock and the natural resources such as forage, soil, and water.

Stockmen and range administrators have long endeavored to estimate the numbers of livestock that their ranges would support; yet today depletion is apparent over a large part of the western range (*28*). Most of this low condition is the result of overly close and repeated cropping that took place in advance of research guidance.

Setting Up Range-Use Standards

The basis for use standards is the degree of grazing that the primary species on representative range units will withstand (*54*, *55*, *56*). The measure of safe use is commonly expressed in a percentage of average leaf length (or stubble height) and number of flower stalks that should remain when grazing ends. The standard set up is influenced by various factors such as quality of site, climate, and range condition. For example, a 3-inch stubble of blue grama in the Southwest would leave more of the season's growth than occurs in all the rest of its height growth and would be wasteful of forage; but a 3-inch stubble of slender wheatgrass in the Northwest would represent too close cropping, and would harm the stand. Ordinarily, from 35 to 50 percent of the current volume (by weight) of forage should remain at the end of the grazing season. Use studies have been carried out in many parts of the West under experimental control and according to stock-

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standards: clipping experiments with representative forage species to simulate grazing, and pasture studies.

Clipping Experiments. Systematic clipping in the West proved helpful in noting the relative grazing endurance of different forage species and pointed out the importance of recognizing the degree of grazing use (*45*). The physiological results of these tests were reported in Chapter 3.

Although these studies had several inherent disadvantages, such as clipping at a uniform height and failure to note height-weight relations (*25, 27, 46, 53, 57*), they brought out the following: (1) forage and seed-stalk production varies inversely with the number of clippings; (2) grasses of dissimilar growth forms respond differently; (3) frequent spring clipping causes the heaviest decline in yield, vigor, seed production, and root growth (Fig. 80), especially during drought periods; (4) setting up practical demonstrations of grazing intensities is necessary.

Pasture Studies. Sheep, cattle, and more limitedly deer, have been used to demonstrate grazing capacity and proper forage use on fenced areas in several western range regions. The earlier tests were set up to demonstrate variation in grazing capacity of the forage acre (Chapter 18), later trials to determine the effects of season and closeness of cropping on individual forage species and on the cover as a whole (*17, 26, 32, 36*).

Variation in Use Standards

Regardless of the condition of a range area, forage production varies from year to year because of fluctuations in rainfall and its distribution (*40, 42*). Droughts are so frequent on the western range as to enter specifically into management planning. In high-production years the abnormally large amount of forage remaining is not wasted but forms needed mulch. Stocking should not be increased, for rainfall below normal may occur in a season or two. The rule of stocking on the basis of slightly below-average growth years should never be overlooked.

On lower-quality sites and on ranges in poor condition, grazing should be sufficiently light to build up plant vigor and allow for some seed formation. As a rule about 60 percent of the current forage volume and 25 percent of the flower stalks should be left on such areas.

Use of the range-condition-survey method is exceedingly helpful in showing what parts of a range area especially need improvement. The procedure entails mapping of the soil types to determine land capabilities (*7*), supplemented by photographs, a descriptive report,

ing rates Removal of forage beyond the average upon which the standards are based has resulted in thinning out the palatable plants, in accelerated erosion, and, eventually, in decreased livestock gains

The earliest attempts at setting up some guidance of allowable range use in the West were made by stockmen, public administrators, and pioneer investigators (*59*, *63*) who leaned on experience and ocular

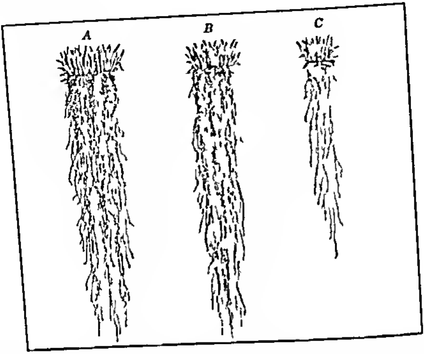

FIG. 80 Trends in root development of slender wheatgrass (*Agropyron trachycaulum*) after clipping of field plots at different frequencies for one season Plants represented by *A*, *B*, and C were clipped 1½ inches above ground surface one, two, and four times respectively at monthly intervals Many plants died after being clipped four times for 2 years in succession

judgment Officials of the U S Forest Service were among the first to set up use standards of a somewhat technical nature soon after these lands were placed under administration They advocated leaving 10 to 15 percent of the volume of current herbage as protection against range depletion In its revised code (1936) the Forest Service required that 10 to 25 percent of the palatable vegetation and about 25 percent of the seed stalks be left at the end of the grazing season This code is essentially what was advocated by Sampson and Malmsten (*57*) in 1926 But it was left to later workers (*2*, *14*, *15*, *16*, *36*, *37*, *39*, *43*, *51*) to propose more exacting means of recognizing proper use

Two procedures were followed in developing the philosophy of use

pearance; (3) sufficient forage should be left to hide squirrel mounds, livestock trails, and the like when viewed from a distance of 20 feet; (4) forage under shrubs and around rocks should be only lightly cropped; (5) a large proportion of seed heads of the less preferred grass

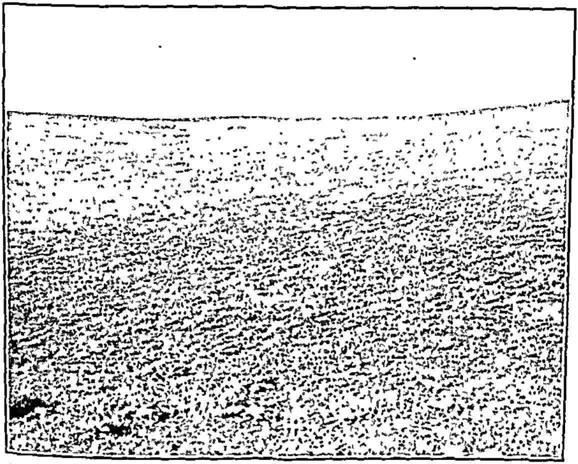

FIG. 81. Indicators of too close grazing on annual foothill range: turkey mullein (*Eremocarpus setigerus*) often occurs on poor-condition range of this kind. Dry plant cover left on ground after heavy grazing averages about 1 inch in height, and the area has a smooth, slicked-off appearance. Small rocks, as well as squirrel and gopher mounds, are visible from a distance of 20 feet.

species should remain ungrazed; (6) bur-clover seeds should be moderately abundant on the ground surface where this species is common (Fig. 81).

The use standards mentioned here are subject to adjustment according to local conditions.

Use Standards for Browse Ranges

Although proper use of the large acreage of browse ranges is of great importance, they have received relatively little study.

Where highly preferred grasses and forbs compose 35 percent or more of the range forage, use standards should ordinarily be focused

and a map to show locations of the range condition classes (Chapter 16) From the facts noted, rational utilization adjustments may be made to improve the units below good condition

Use Standards for Grass and Forb Ranges

Standards for these plants are commonly based on leaf length or stubble height

In the Southwest, Crafts (*17*) found that when blue grama (*Bouteloua gracilis*) was cropped within 2 inches above ground, 92 percent of the height growth was grazed, 55 percent of the volume taken, and 45 percent of the volume left Such average height represented allowable use for this plant, which has most of the forage volume concentrated in the lower 2 or 3 inches Curly mesquite, with a slightly different growth pattern, requires a stubble height of about 3 inches (*4*, *17*), Arizona fescue (*Festuca arizonica*) 5 inches, and side oat grama 4 inches (*18*)

On mountain range in the Northwest, Pickford and Reid (*50*) reported that an average leaf length of not less than 3 inches should be left to maintain such useful species as bluebunch wheatgrass (*Agropyron spicatum*), Sandberg bluegrass (*Poa secunda*), and green fescue (*Festuca viridula*) A similar leaf length should remain on meadows dominated by tufted hairgrass (*Deschampsia caespitosa*) and associated species (*51*), leaving about 50 percent of the current growth ungrazed

In the central Great Plains, Costello and Turner (*14*) concluded that blue grama and buffalo grass (*Buchloe dactyloides*) should have a stubble height of 1¾ inches in good growth years and 1¼ inches in poor years The lower stubble height in poor years is due to the reduced height growth of these plants

Where a large part of the forage cover is composed of two primary species one of which has a higher preference rating (palatability) than the other, the use standard must be geared to the plant with the highest preference For example mountain muhly (*Muhlenbergia montana*) and Arizona fescue (*Festuca arizonica*) often predominate on timber ranges in northern Arizona When the more relished muhly is grazed to the standard adopted the range should be regarded as properly used even though the fescue is underutilized according to its standard (*16*), otherwise the muhly would be cropped excessively and the range as a whole would be overutilized

On California annual grass ranges, Hormay and Fausett (*31*) found that units in satisfactory condition have the following appearance (1) adequate mulch, and average stubble height should be about 2 inches, (2) the remaining vegetation should have a mottled patchy ap-

pearance; (3) sufficient forage should be left to hide squirrel mounds, livestock trails, and the like when viewed from a distance of 20 feet; (4) forage under shrubs and around rocks should be only lightly cropped; (5) a large proportion of seed heads of the less preferred grass

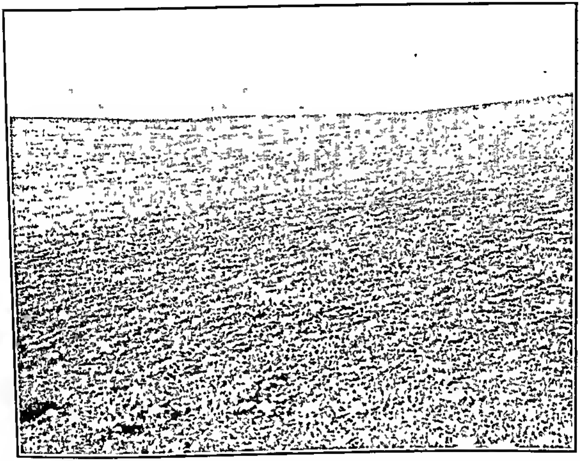

Fig. 81. Indicators of too close grazing on annual foothill range: turkey mullein (*Eremocarpus setigerus*) often occurs on poor-condition range of this kind. Dry plant cover left on ground after heavy grazing averages about 1 inch in height, and the area has a smooth, slicked-off appearance. Small rocks, as well as squirrel and gopher mounds, are visible from a distance of 20 feet.

species should remain ungrazed; (6) bur-clover seeds should be moderately abundant on the ground surface where this species is common (Fig. 81).

The use standards mentioned here are subject to adjustment according to local conditions.

Use Standards for Browse Ranges

Although proper use of the large acreage of browse ranges is of great importance, they have received relatively little study.

Where highly preferred grasses and forbs compose 35 percent or more of the range forage, use standards should ordinarily be focused

on the herbaceous cover (*32*). This is justified because of the relatively high feed value of the combination of browse and herbaceous forage and the relatively greater soil protection afforded by the herbs.

Forsling and Storm (*26*), working in southern Utah, found that the browse was best maintained where it was not cropped too early and where one or more lateral buds were left on each twig. This would usually require that at least 20 percent of the current growth be left uncropped (*57*). Where about 15 percent of the current growth of the less preferred shrubs was taken, the highly palatable browse species were properly utilized.

Working with bitterbrush (*Purshia tridentata*) in northeastern California Hormay (*30*) reported that close browsing in successive years is the chief cause of its deterioration. About 40 percent of the season's twig growth should be left to maintain desired vigor and induce seed production. Percentage utilization was computed from estimates of grazed and ungrazed twigs. Where bitterbrush composes 25 percent or more of the total forage and is being cropped too heavily, reduction in livestock numbers is advisable. Where this shrub composes only a small part of the forage crop, even light grazing will cause excessive use. An occasional season of protection from grazing is recommended. Management of many other highly preferred browse species is much the same as that for bitterbrush.

In northern Idaho, Young and Payne (*65*) found that redstem ceanothus (*Ceanothus sanguineus*)—a highly preferred sheep and goat browse—was not injured when 75 percent of the current twig growth was cropped in spring and/or fall but was damaged in early summer when 50 percent or so of the season's twig growth was removed. They proposed to reserve areas dominated by this browse for late summer or early fall use. Cropping up to 60 percent of the current twig growth was regarded as satisfactory for this and other highly palatable browse species of that region.

Measurement of the utilization of browse vegetation is tedious (*34, 52*). Nelson (*41*) recommended the traverse board method of outlining the surface area of each browse plant or of individual branches on selected plots, setting up the plane table over permanently staked locations to facilitate repeat mapping. Most other methods used are adaptations of the quadrat procedure, such as counting the numbers of squares of canopy by placing an overhead wire or cord frame suspended on portable stakes. This technique is useful in line transect sampling, since the frame is readily moved along the line as the work progresses.

Forage Preference and Proper-Use Factor

Forage preference expresses the relative "likeability" of forage species by grazing animals when given free, unhurried choice on the range. In the earlier literature (*23*), *palatability* conveyed this same idea. Later, palatability was used to express proper use, but now it implies the original meaning of preference (*60*).

The term *proper use* implies the degree of grazing that an individual species, or the total palatable cover of a range area, may endure without damage to it or the soil. And the *proper-use factor* for a range association is the weighted average, expressed in percent, of the proper-use factors of its dominant individual plants.

Forage preference more than any other single factor determines the kind of stock that will make the best use of a range unit. Horses and cattle do best on grassland, but cattle also consume many forbs and some shrubs (*13*, *22*). Sheep prefer browse and forbs but feed on a greater variety of plants than cattle and horses. Goats are predominantly browse eaters, and the practice of using them to eradicate brush is sometimes effective and profitable (Chapter 13). The different species of big game animals also have distinctive food preferences (Chapter 22). The season of grazing is also of great importance in securing the best forage use and in maintaining desirable range condition.

Determination of Range Use

Range use is determined by either the *ocular* (*qualitative*) or the *measurement* (*quantitative*) approach.

Ocular or Qualitative Approach

Five fairly distinct methods have been most commonly employed in applying this approach.

1. General Reconnaissance. The inspector estimates utilization by looking over the range systematically (Chapter 18), and comparing undisturbed growth, as on protected areas, against the grazed range. This method is fast, since no plants are measured and few if any plots are used. But, since vegetal density, plant composition, and range condition are merely estimated, various examiners might get rather different results (*58*).

Several refinements of the reconnaissance method have been made. The most useful of these is the weight estimate by plot method for determining forage yield and calculating stocking rates.

2. Ocular Estimate by Plot. This method, evolved by Pechanec and Pickford (*48*), is a refinement of the reconnaissance procedure.

It entails the use of many plots selected at random and small enough so their entire area can be seen from one point. Visual estimates of degree of cropping are made in percentages of the total weight of each species removed from the plots. Accuracy of the estimates can be checked statistically by clipping and weighing the forage on the plots. This method is free from detail and relatively rapid and inexpensive, and personal error in judging individual plots tends to be compensatory.

3. **Ocular Estimate by Average of Plants.** Pechanec and Pickford (*49*), desiring to refine observations of the ocular-estimate-by-plot method, critically studied the utilization of individual grass species. The percentage of herbage removal by height is noted for each important forage plant on the plot, and the average of these estimates is taken as the percentage utilization for the plot. These authors favor this method, because it is relatively free from personal error and shows a high correlation with the volume of forage removed. Numerous replications can be made without excessive cost. It is designed for use on bunchgrass range. A similar technique was proposed by Canfield (*6*) for southwestern ranges.

4. **Photographic Method.** Hormay and Fausett (*31*) determined utilization on California annual ranges with photographs and range descriptions. The grazed appearance of the range is matched against a series of photographs showing different degrees of use, described as light, moderate, or heavy. On a numbered scale moderate or proper use is designated as 60. Higher rating indicates too close, lower rating too light use.

5. **Primary Forage Plant.** This method, described by Deming (*24*), employs a visual-use standard. Designed primarily for range administrators, a unified outline is followed in re-examining an adequate number of permanently established, randomized plots, preferably at the close of each grazing season. The observations are centered on the plants that bear the major grazing load. The information gathered includes description of the plots, soil condition, topography, degree of grazing; and abundance, mortality, or reproduction of the primary forage species. The summarized data are used to designate for each plot one of nine degrees of relative grazing use: unused, slight, light, moderate, proper, close, severe, extreme, or destructive. *Proper* use implies leaving one-third of the current shrubby growth and at least one-fifth of the current leafage of grasses and forbs. *Extreme* use depicts a cleanly swept or stripped appearance of the vegetation, accompanied by conspicuous trampling. The method is simple and applicable to range lands generally.

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Measurement or Quantitative Approach

Three methods have been used in this approach: weight measurement, height measurement, and stem-count measurement.

1. Weight Measurements. Beruldsen and Morgan (*1*) of Australia were among the first to determine range use by weight, when they compared the amount of forage cropped by sheep with that produced under wire cages or in exclosures. The difference in dry weight between the two sets of clippings was the percentage utilized. Although this method is reasonably accurate and suitable for small experimental units, it is not applicable to large range areas, because it requires a fenced or a mature vegetation as a check.

Several cage- or enclosure-weight methods by clipping have been reported. A joint committee of agronomy, dairy, and animal production associations (*33*) proposed a technique for use during the growing season, which took into account the aftermath. The method employs a series of two plots, each 1 meter square, placed at random and protected from grazing by wire cages. A third plot, 1 meter square and unprotected, is located within 10 feet of the protected ones, where the vegetation is similar. The plots are clipped at 2-week intervals during the growing season, after which new locations are established. The volume of forage grazed is determined after each clipping by subtracting the yield of the unprotected plot from that of the caged plots. The total of these calculated weights should closely approximate that of the forage grazed. This method, similar to a technique proposed by Klingman *and associates (35), is chiefly suitable for use on small* pastures.

Cassady (*8*) proposed a utilization method on sheep range by collecting and weighing fresh samples on a predetermined number of plots immediately before and after grazing. Utilization was determined by comparing the difference in weights of the forage on the two sets of plots.

2. Height Measurements. Stockmen and pioneer forest rangers were first to express utilization in terms of the height growth that should be left. Although they proposed leaving 15 to 20 percent of the current growth as protection against overuse, they had no yardstick for measuring utilization.

Pechanec and Pickford (*48, 49*) have demonstrated that the percentage utilization of grasses is equal to the reduction in their average leaf length (height) as a result of grazing. Enclosures are employed if the range is grazed during the period of rapid growth. At the end of the grazing season percentage utilization is calculated from the differ-

ence in average leaf height of the primary species on the grazed and the ungrazed areas Where little growth takes place after measurements, as on areas of mature forage, the use data seem to hold up well Preference and abundance in the stand of forage species are given consideration Plots of various shape as well as transects may be used in securing the data (*11*, *14*, *51*)

In the Southwest, Canfield (*6*) proposed a method that is based on the idea that the percentage of a grass cover cropped closer than a 2 inch stubble height is proportional to the percentage grazed to a height greater than 2 inches and to the ungrazed forage (*5*) When the percentage of 2 inch grazing is known, the associated percentage of partly grazed and the percentage of ungrazed forage may be read directly from stubble height distribution curves A chart or graph must be made for each new grass cover The method is rapid and accurate to within 10 percent

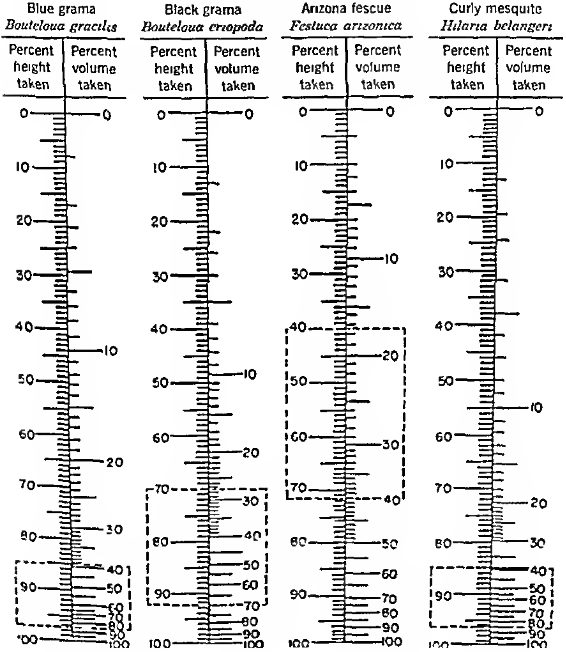
Lommasson and Jensen (*37*, *38*) were the first to show differences in the form factor (shape) of grasses by correlating height removed with weight removed Grass samples were collected at random. When in flower or seed, leaves and culms of each specimen were held in place by wrapping them spirally with a string before the plants were clipped near the ground line Average maximum height of each sample was obtained by recording the tallest flower stalk and the longest leaf of plants without flower stalks Each plant was cut into 1 inch (in some instances 2 inch) segments and weighed air dry The data were recorded in a summarized table from which form factor curves were constructed showing percentage data of height and weight per segment in relation to the plant as a whole Details of procedure are described by Lommasson and Jensen (*37*, *38*) and others (*3*, *12*, *16*, *17*)

The height weight (form factor) principle appears sound and gives more uniform results than the ocular method (*38*), but it is more tedious However, Clark (*10*), working on mountain range in Utah, found that composite samples for 4 years from different zones showed considerable error when average height weight tables were used Greatest variability in height occurred in good growth years

Special impetus was given to the form factor idea (Figs 82 and 83) by Crafts (*17*) and his associates (*16*, *18* *19*, *20*, *21*) in the Southwest. Campbell and Crafts (*4*), for example, found that the height weight chart affords a simple field utilization measurement of range grasses. They verified the fact that the major part of the leafage (by weight or volume) is in the lower 2 or 3 inches of the plants studied

Campbell (*3*) reported three rather distinct forms of height volume relations among grasses (Fig 84) Bottlebrush squirreltail was found

to have a nearly straight line height-weight relationship, the weight being distributed nearly uniformly throughout the length of the plant. Blue grama forms a rather steep height-weight curve for the upper half of the plant, which becomes much less precipitous as the volume of forage increases in the lower half. Sandberg bluegrass has an "S" curve, because of abundant basal leafage and heavy seed heads to add



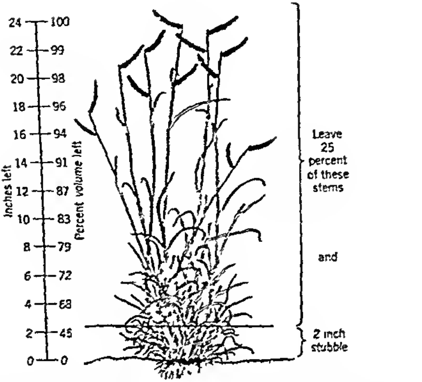


FIG. 83 Illustration of proper use of blue grama (*Bouteloua gracilis*). About 75 percent of the number of culms and nearly half of the forage volume should be left. An average stubble height of 2 inches, or 12 percent of the total height, would leave about 45 percent of the forage volume. [*After Crafts and Glendening* (20).]

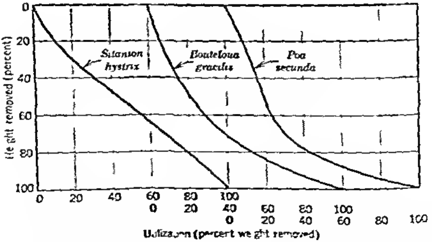


FIG. 84 Height weight curves (form factors) of range grasses with seed stalks: bottlebrush squirreltail (*Sitanion hystrix*), blue grama (*Bouteloua gracilis*), and Sandberg bluegrass (*Poa secunda*). [*After Campbell* (3).]

weight to the uppermost portion. Plants without seed heads make a somewhat different form-factor curve than the species illustrated here.

The author, working with height-weight relations of wild oat (*Avena fatua*), an annual, and needlegrass (*Stipa pulchra*), a perennial, also found appreciable differences in the form factors of these plants (Fig. 85).

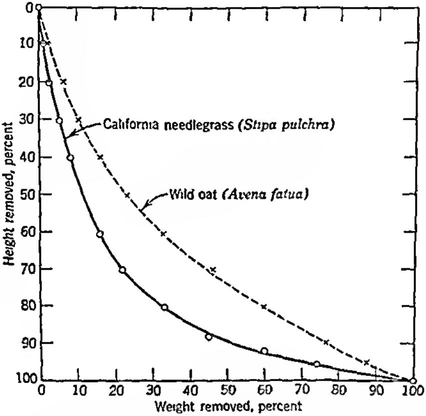


FIG. 85. Forms of height-weight curves of wild oat (*Avena fatua*), an annual grass, and purple needlegrass (*Stipa pulchra*), a perennial bunchgrass. The significantly greater volume of herbage in the lower half of the needlegrass is due to its abundant basal leafage.

Height-weight charts or "slide rules" prepared for field measurement of utilization have proved helpful. Valentine (*64*) marked off a card at full scale (1 inch = 1 inch), then placed it along plants to measure stubble-height in percentage weight removed. The data could be recorded at a relatively rapid rate.

Parker and Glendening (*43*), working in the Southwest, took into account all the important forage species rather than a selected few. They recorded percentage composition and calculated the percentage of proper use and the proper-use factor for the area concerned. The data were supported by such factors as erosion, livestock management, and forage production.

The height-measurement method has clarified various important utilization questions, most significantly perhaps the recognition of the form factor. Since this method has evolved through experimental procedure it is sound and should prove more useful with further study.

3. Stem Count. Stoddart (61) proposed this method after concluding that percentage utilization was correlated with the total grazed number of stems of western wheatgrass (*Agropyron smithii*). The number of grazed stems on randomized plots were recorded at 2-week intervals and continued until the range was fully utilized, though the record taking could be delayed until the end of the season. The percentage utilization was computed by comparing the data from the check (ungrazed) area with utilization of comparable grazed unit.

Although the method is rapid and simple, it has an inherent weakness, because the percentage of stalks grazed is not always correlated with the percentage volume of herbage taken (47). Therefore, a conversion factor of stalks grazed to volume utilized at different intensities must be determined for each species measured.

Key Areas and Key Species

Key Areas

The key-area concept for checking utilization is based on the fact that it is essentially impossible to achieve uniform grazing over a diversified range unit, also, that it is not financially feasible to examine an entire range area. Excessive use around watering places, salt grounds, stock driveways, and accessible meadows is unavoidable, particularly on cattle range. Underuse or nonuse is common on steep hillsides and areas remote from water. Full but allowable use of the inaccessible areas would result in extreme abuse of the better units. For these reasons the intermediate areas—those not overly steep or remote from water, which furnish most of the feed—should constitute the *key* or representative areas upon which to gauge proper use of the range as a whole. A good key area should be moderately easy rather than too easy for the stock to reach, and soil and vegetation should be as representative as possible of the unit generally. But concerted effort should be made to reduce the size of the so-called sacrifice areas—those normally overgrazed or undergrazed—as far as possible.

Key Species

Because of the many plant species present on most ranges, each of which may be utilized according to its availability and preference, it is necessary to base utilization calculations on a few important plants

Key species should preferably be those that endure moderately close grazing, and they should be fairly or potentially abundant (*9, 21, 62*). Just as there are certain sacrifice areas there are also some sacrifice plants—species with high animal preference but never abundant in the stand. These "dessert" or 'ice cream' plants are usually killed out when the hardier, more abundant, and somewhat less highly preferred key species are properly utilized, a fact that entails little economic loss. Usually no more than two to four key species are selected for observation or measurement of utilization on a key unit. Occasionally, proper use may be judged by the degree of cropping of a dominant, single, first-class species. In the Southwest, blue grama may be a key plant on units where it is actually or potentially dominant. When this species is properly utilized the range as a whole is properly grazed. But where blue grama occurs in association with other equally abundant and preferred grasses the range is considered suitably cropped when all the key species are properly utilized (*44*).

Choice of Utilization Method

Each of the utilization methods described has some merit. The technique to be selected will depend largely on the accuracy of the use records required.

In range research, where a high degree of accuracy is essential, one of the measurement methods is desirable. For this purpose one of the height-weight procedures should serve best (*4, 20, 38*). On small, intensively grazed farm pastures one of the cage or enclosure methods should give good results (*1, 35*).

On large, commercial grazing grounds the ocular estimate by average-of-plant method—an adaptation of the reconnaissance procedure—was recommended by Pechanec and Pickford (*49*) after critical study of methodology. This method is rapid and adaptable to a wide variety of conditions, is sensitive to irregularities in utilization, and is relatively free from personal error. The authors did not advocate use of any of the more refined measurement methods on large range areas.

Not to be overlooked on any range is the range condition survey procedure. The expense of preparing a map upon which to delimit the condition classes and of proposing adjustments in utilization is neither excessive nor overly technical.

Problems of Seasonal Utilization Adjustments

By using the factors of time, animal numbers, and forage consumed, it is possible to foresee any necessary adjustments in animal numbers

in the interest of proper use and meat production The relation of these variables may be expressed mathematically as follows

$$\frac{\text{Forage remaining}}{\text{Forage utilized}} = \frac{\text{Animal time units remaining}}{\text{Animal time units used}}$$

The amount of forage utilized may be judged by estimating or measuring the degree of grazing of one or more key species The forage remaining is ascertained by noting the difference between the total forage produced and the forage utilized The solution of certain unknown factors may be illustrated by two examples.

One Key Species Example

Bluebunch wheatgrass is the key species on a range grazed by 1500 cattle The grazing season extends from June 1 to November 1 A utilization survey on September 1 shows that the average height of bluebunch wheatgrass is 5 inches on grazed plots and 23 inches on ungrazed plots Proper use for this grass is 50 percent of its current growth What adjustments are necessary in livestock numbers or length of the grazing season for proper utilization? The height weight relations of bluebunch wheatgrass are shown in Table 22

TABLE 22

Height Weight Relations of Bluebunch Wheatgrass

Stubble Height of Forage (Inches)	*Weight Utilization* (Percent)	*Stubble Height of Forage* (Inches)	*Weight Utilization* (Percent)
23	0	10	14
20	1	8	22
18	3	5	45
15	6	3	67
13	8	0	100

Solution With a stubble height of 5 inches 45 percent of the forage has been used, and with 50 percent use being proper, only 5 percent remains to be used From June 1 to September 1 1500 cattle have grazed the area, which amounts to 4500 cow months of use Substituting these values in the equation previously stated, cow months remaining may be solved as follows

$$\text{Cow months remaining (495)} = \frac{5\% \text{ (forage units remaining)}}{45\% \text{ (forage units used)}} \times 4500 \text{ (cow months used)}$$

The adjustment necessary would be to shorten the grazing season to 33 month (495 cow months/1500 cows) or reduce the number of

cattle to be grazed from September 1 to November 1 to 248 cows (495 cow-months/2 months)

Several Key-Species Example

When more than one key species is used, each species must be weighted according to abundance in the forage composition Suppose that two key species are employed and that a utilization check gives the results shown in Table 23.

TABLE 23

Utilization Check, Two Species

Species	*Composition (Percent)*	*Utilization (Percent)*
Slender wheatgrass	40	50
Sandberg bluegrass	30	60

The proper-use factor for slender wheatgrass is 80 percent and for Sandberg bluegrass 60 percent Forage used and total forage available are shown in Table 24

TABLE 24

Forage Used and Available, Two Species

Species	*Forage Used*	*Forage Available*
Slender wheatgrass	40 × 50 = 20	40 × 80 = 32
Sandberg bluegrass	30 × 60 = 18	30 × 60 = 18
Weighted totals	38	50

Once these weighted values are obtained the computation of animal-time units remaining is identical with that of the problem involving one key species

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RANGE INVENTORIES AND MANAGEMENT PLANNING

The primary objective of a range inventory, or survey, is to assemble all important facts needed for perfecting a sound management plan. A range survey deals with the broader aspects of the handling of a range area, hence it takes into account the physical and vegetal conditions as well as the proper balance between grazing and other resources of the land (*18*). Until recent years, range surveys have mostly been concerned with large areas.

Much of the data from a survey is recorded on maps or overlays of suitable size for subsequent field use. Considerations are noted for each range unit, such as the number of animals grazed, grazing capacity, period of grazing, a salt plan, needed water development, areas in need of revegetation, better livestock distribution, and the location of special problem areas. Assembled in tabular or other convenient form, the basic data are used for the formulation of a suitable action program (*6*).

By 1950 slightly more than one third of the western range region had been surveyed and management plans put into operation, primarily through Federal agencies. In the past, most range surveys were conducted on public range, but now Federal and state agencies also survey private ranges.

Range survey procedure has been more or less standardized in recent years, but rigid management planning applicable to diverse climatic and forage regions has proved impracticable.

Range surveys also have the additional value of providing excellent training for young men who make up the survey parties.

Classification of Forage Types

Range-survey maps should give complete and accurate cultural data and management information, showing all forage types and subtypes. The following eighteen types (with their standard map colors, designated by crayon numbers) have been adopted by the Inter-Agency Range Survey Committee (*4*) for mapping the western range region (Table 25).

TABLE 25 (*Continued*)

Type Number	*Type Characteristics*	*Type Color**	*Remarks*
10 Broad-leaf, deciduous trees (Fig. 87)	Cottonwood, aspen, oak, birch, alder, ash, elm	Pink Mongol-846	
11 Creosote bush	Creosote bush dominant	Bottle green Mongol-855	
12 Mesquite	Mesquite dominant	Yellow earth Mongol-853	
13 Saltbush (*Atriplex*)	Saltbush dominant; separate from desert-shrub type	Slate Mongol-819	Atriplex is sufficiently dominant to show type
14 Greasewood (*Sarcobatus*)	Where *greasewood* is dominant, valley floors	Royal purple Mongol-864	Overflow areas, with saline soils
15 Winterfat (*Eurotia*)	Where winterfat gives characteristic aspect	Light tan Mongol-813	Becomes a type in Utah and Nevada
16 Desert shrub, general type	Blackbush, goatnut, cat's claw, hop sage	Dark tan Mongol-863	Hop sage, horsebrush, rabbitbrush, etc.
17 Half shrub	Snakeweed, burroweed, buckwheat, fringed sagebrush	Wisteria Mongol-844	Seldom of sufficient size to type
18 Annual weeds	Annual weeds, downy chess, six-weeks fescue	Red terra cotta Mongol-876	

Land formerly cultivated but now abandoned should be classified according to the surrounding areas, preferably with their boundaries hatched in mapping.

Techniques of Vegetation Analysis[1]

Three different procedures have been developed for conducting range surveys: (1) the reconnaissance survey method, (2) the square foot density survey method, and (3) the range condition method.

Reconnaissance Survey Method

In 1910, Jardine and Anderson (5) proposed a technique of ocularly estimating the percentage density of the ground cover of vegetal "types"

[1] To clarify this discussion, terms commonly used in range surveys and grazing plans are summarized at the end of this chapter.

FIG 86 Meadow type (Type 2) in foreground with waste range of dense timber (Type 7) in background [*From* Range and Pasture Management, *by the author* (*10*)]

FIG 87 Sagebrush type (Type 4) in foreground and aspen subtype (Type 10 broadleaf trees) in background Aspen is a valuable cover because of the luxuriant understory of palatable vegetation that it characteristically supports [*From* Range and Pasture Management, *by the author* (*10*)]

covered with vegetation (10/10 density), as observed from directly above, an oblique view may bring about distortion (Fig 88) In estimating density of shrubs, only current twig growth within reach of the stock is considered not higher than 30 inches from the ground for sheep or 60 inches for cattle Density estimates are checked once or twice daily, as the mapping proceeds The inexperienced worker

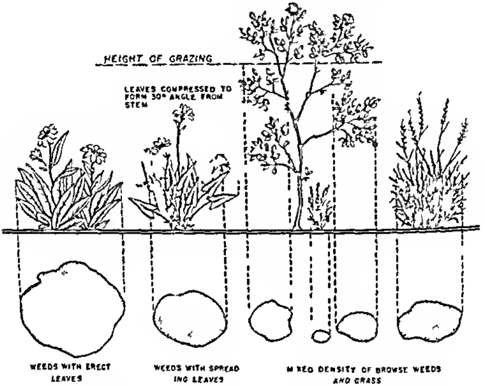

Fig 88 Projectional illustration of densities of browse, forbs and grasses

can do this by digging up the herbaceous plants in random plots and placing them together in a square-foot area without excessive compaction, to form a 100 percent density Since the plot area is 100 square feet, 1 square foot of area occupied by a species represents 1 percent cover The density of the type or subtype is regarded as equivalent to the average number of square feet of each species per 100-foot plot The forage acre factor of each type is obtained by multiplying the average density of each species by its proper use factor (P U F) and then summarizing these values for the entire composition The method is illustrated in Table 26

The best season for estimating density is when the important forage species are at or near maximum development (6) Fenced enclosures are helpful in judging pre- or post-season density and composition

TABLE 26

SQUARE FOOT DENSITY SURVEY METHOD

Species	*Plots* (square feet) I	II	III	IV	V	*Average Density* (percent)	*P U F for Cattle*	*Density* × *P U F*
Poa	3	4	5	3	5	4	70	028
Lathyrus	6	6	5	4	4	5	70	035
Agoseris	4	5	3	5	3	4	50	020
Cercocarpus	7	8	7	9	9	8	80	064
Quercus	10	5	8	7	5	7	20	014
						Forage Acre Factor	=	161

In 1937 the square foot density method was adopted by Federal agencies as a standard range inventory procedure (*4*) However, both the square foot density method and the reconnaissance survey procedure rely on the density factor as the only measure of the volume of vegetation, a measure that has not shown especially close correlation with actual weight studies (*13, 15*) Dasmann (*1*) concludes

> One way to eliminate the troublesome density element from forage inventories would be to substitute actual weight of forage on randomized plots as determined by clipping and weighing The yield could then be expressed in pounds of forage per acre

RANGE CONDITION SURVEY METHOD

This technique appraises the reaction of the range to the grazing practice in operation The appraisal is essentially based on plant successional trends the stability of the soil and the potential capacity of the site (Chapter 16)

The condition survey method has been employed by the Soil Conservation Service since 1942 (*3, 9, 22*) Among the facts noted in the field are plant composition vigor of key forage species, forage density, volume of growth by clipping of plots degree of erosion amount of mulch present, and condition classification of each range unit (*16*) Once the standards of proper utilization for each condition class have been determined for an area they can be adapted to other range units of the same general region

The condition survey method is gaining in popularity partly because it is simpler than the reconnaissance and square foot density methods and also because these survey methods do not provide specifically for classification of "condition" of the range

For the condition survey method the range area must be classified by major ecological associations and mapped according to sites (*3*)

Since not all areas have identical productive possibilities, those differing perceptibly in potential capacity are separately mapped and described Within a major site each range segment is rated as to its condition class excellent good fair poor, or very poor In field mapping the examiner must first recognize true ecological associations and not mere 'types' or subtypes Humphrey (3) points out

In the Pacific Northwest types consisting mainly of cheat grass brome, sagebrush, or perennial weeds are denoted as condition classes within bunchgrass or some other climax type not as types *per se* This places the emphasis where it belongs—on the present vegetation considered in terms of the ultimate production of forage on the area

In this new method the condition of a site is determined, not by comparing its productivity with that of some other more or possibly less productive site, but by comparison with sites having similar productivity The classification is therefore, one of productivity of site potentials

Field application of the range condition method of survey is simple and direct *First*, the technician prepares brief descriptive guides for the area regardless of its condition *Second*, each of the range condition classifications—excellent good fair, poor or very poor—is described on a special field sheet for each major ecological type, and may be illustrated by photographs also noted are the management features recommended to maintain or improve the condition of the range The condition class description takes into account such features as forage density, forage vigor indicator plants litter, and erosion Under the heading of 'management are noted the present plan of grazing, season of use, number of stock grazed allowable grazing use, and potential forage production (Chapter 17) An aerial photograph or map is available to the field man showing boundaries of the different ecological units, and condition class guides of these units are provided Generally, only the main forage species need to be recorded

Figure 89 illustrates a range area mapped according to the condition method A proposed change in management, based on the range condition classes is shown by relocation of the fence, and development of water and placing of a windmill

Field Mapping and Note-Taking

Preliminary Considerations

Before beginning field work the survey party leader assembles all needed equipment and important administrative information Included

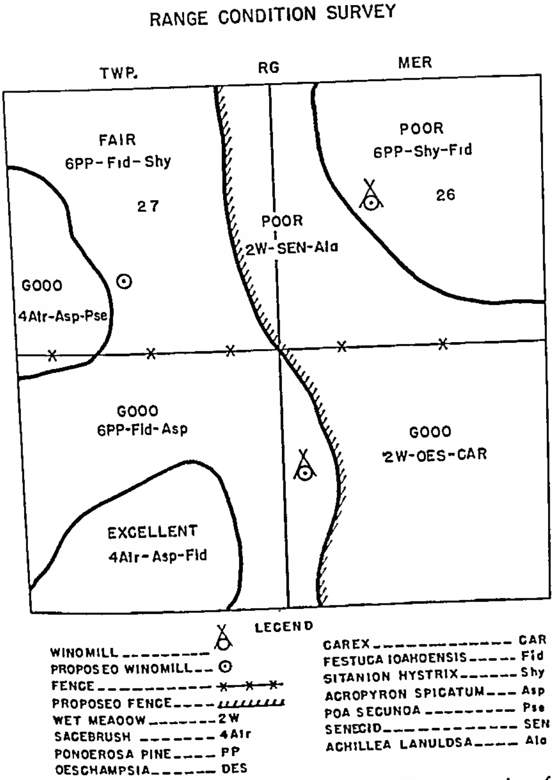

Fig. 89 Map showing a range condition survey of four sections where four different range condition classes occur. Relocation of the present fence and selection of a place to develop additional stock water, as shown on the map, should, with proper livestock handling, result in vast improvement in the condition of the area This illustration also designates types used in the reconnaissance and square foot density methods

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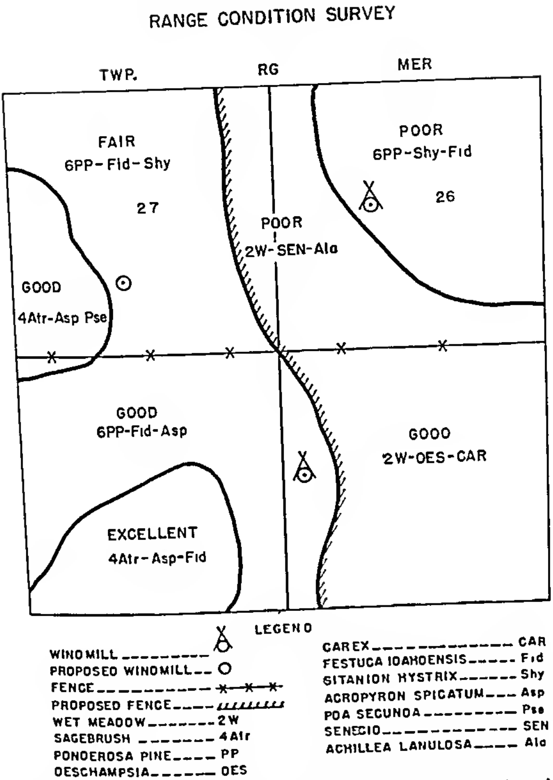

Fig. 89 Map showing a range condition survey of four sections where four different range condition classes occur. Relocation of the present fence and selection of a place to develop additional stock water as shown on the map should with proper livestock handling result in vast improvement in the condition of the area. This illustration also designates types used in the reconnaissance and square foot density methods.

well defined, this system may be combined with the gridiron technique (*18*).

Plane Table System. This method is useful in rugged, unsurveyed or partly surveyed country where several high, bare peaks and treeless ridges are intervisible. The mapping of type and cultural features is accurately done by point intersection, the forage being estimated by passing through typical portions of each type while traveling between vantage points or control stations. Only men with experience in surveying and plane table work can successfully employ this system.

Aerial Base Map System. An aerial photographic base-type map must be available (*21*). In preparation for mapping, type boundaries and prominent cultural features may be shown on the map. Less discernible subtype and cultural features are sketched in as the field work progresses while the examiner also corrects the type boundaries where necessary. Control for additional mapping is obtained from G.L.O. corners, triangulation stations, prominent points, and by other survey techniques. Each examiner plans his route for most effective study of his portion of the area.

Direct Field Typing System on Aerial Photographs. A set of topographic and cultural tracings, showing township assemblages, are needed to supplement the aerial photographs. Sketching of types and subtypes, or associations, is done directly on the photographs. After deciding on the drainage that he will work, the examiner selects and studies the appropriate photographs to get a good idea of the types, water, culture, and other features; he then selects a route that will take him through all of the types or associations. Mapping is usually done across drainages, so the examiner can sample differences in elevation and collect forage data on one side of the drainage while sketching in the types on the opposite side. Any important features not visible on the photographs are located by traversing and are then plotted on the tracing or on the reproduction of the tracing. The use of section corners, bench marks, triangulations, and other available points is necessary to locate type boundaries where topography does not delimit the plant cover (*18*). Once the features have been delineated on the photographs they can be transferred to a base map by simple photogrammetric features.

Comparative Costs of Range Survey Methods

Reid and Pickford (*8*) conducted studies on the costs and reliability of the reconnaissance and of the square foot density survey methods.

In these studies the grid and the photographic procedure of mapping control were used

The aerial reconnaissance method gave the most dependable results and was the cheapest if free negatives of aerial photographs were available When the cost of aerial photographs and subsequent construction of base maps had to be paid for from range-survey funds, the grid reconnaissance method, conducted at an intensity of two strips per section was recommended for ranges of gentle topography This method was almost as dependable as the aerial reconnaissance method for such conditions If adequate base maps are not available, or where the topography is rough, the added cost of aerial photographs and the institution of the aerial reconnaissance method appears justified

Comparative tests on the same range area (5) show that the reconnaissance method is less expensive than the square foot density method Prewar surveys using the reconnaissance method cost 9 00 mills (9/10 cent) per acre when mapping was done directly on aerial photographs and 9 09 mills per acre when mapping was done with the grid procedure Comparable work with the square foot density method cost 11 53 mills per acre when mapping on aerial photographs and 9 88 mills per acre when mapping with the grid procedure When aerial photography and subsequent base maps had to be provided there was an additional cost of 7 98 mills per acre

Little is known of the per acre cost of the range condition survey method, since few such surveys have been conducted over large range units, such as a national forest involving thousands of acres Since both the field mapping and the office compilations are less detailed and more direct than those of the other two methods discussed the cost of the completed condition survey should presumably be less

Mapping of Special Features

Regardless of the mapping system used, these special features should be entered on all field maps or photographs character of stock water facilities such as streams, springs, seeps and reservoirs, salt grounds—their condition and the suitability of their location, barriers to stock drift, such as cliffs, ridges, and fences, overgrazed areas, with a critical examination of their needs, poison plant areas, localities infested with rodents, areas inaccessible to stock, and poorly located or excessively used sheep bedgrounds

A feature that has more recently received detailed attention is that of soils their depth, texture, structure, series and the degree and kinds of erosion Symbols have been established for convenience in recording such soil data on field maps

Computation of Inventory Data[2]

In using either the reconnaissance or the square foot density survey method, the only computations made in the field are those determining the forage-acre factors. All other computations are made in the office, usually after the field season.

In the office the survey map is prepared, the grazing capacity computed, and various range-management features are recorded. The types sketched in the field and the symbols of the forage species are placed on the base map. Type (or association) boundaries are then planimetered to determine acreages. A typical summation sheet is shown in Fig. 90, which is the base map of a township. In this instance the field sheets would show that type 1 (*T*), tall grass, is principally composed of *Festuca idahoensis, Agropyron spicatum*, and *Poa secunda*, denoted on the map as *Fid, Asp, Pse.* The planimetered area of the type is 6985 acres.

After the type acreages are determined by sections they are summarized on work sheets and later on a compilation sheet for the township. Designated headings on the compilation sheet are S.A. (surface acres) and F.A. (forage acres). The acreages of the types are assembled within sections, the section being the basic unit rather than the township. The forage-acre factor for each type is obtained from the field sheets. If more than one write-up has been made for a type, its forage-acre factor will be the weighted average of the individual write-ups. The forage acres (surface acres × forage-acre factor) are then obtained for types within sections; by a summation of these figures, by types, the total of forage acres within a township is obtained. Fig. 90, for example, shows that type 2-*D* comprises a total area of 580 acres. Since, in this instance, the F.A.F. for this type, recorded on the field form, is .240, then 580 × .240 = 139 F.A. The process indicated is followed for all types, or by pastures or other management units.

To obtain grazing capacity, the forage acres of a type are divided by the forage-acre requirement. Adopting 0.6 F.A. per cow per month as the forage-acre requirement, the grazing capacity for this type is: 139/.6 = 232 cow-months (Fig. 90). The data for this type are then entered on the map, along with the surface-acre figure, in the following form:

$$\frac{\text{Surface acres}}{\text{Grazing capacity in animal-months}} = \frac{580}{232}.$$

[2] See sample survey problems and calculations presented later in this chapter.

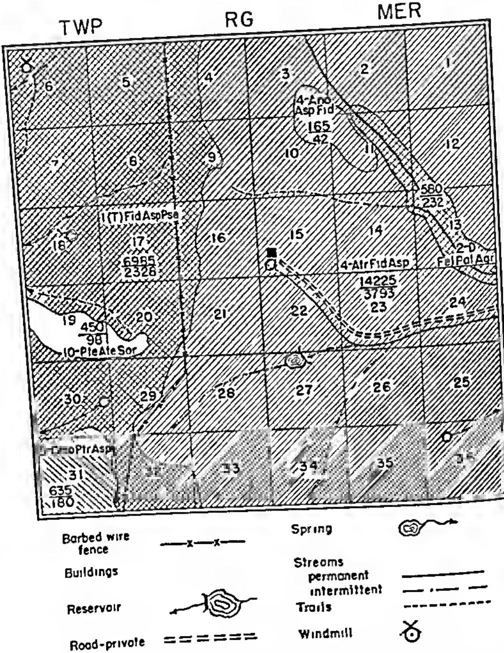

Fig 90 Illustration of a base map of a township showing recorded types subtypes, acreages and computed grazing capacity by types Type 4 covers the largest acreage and is chiefly occupied by *Artemisia tridentata* *Agropyron spicatum*, and *Festuca idahoensis* Other types present are 2D, 1(T), 10 5, and a subtype of Type 4 These types also show the dominant forage species by symbols

To apply a management plan, various alignments of compilation figures must sometimes be made Where, for example, the range is to be divided into fenced units or allotments, the grazing capacity of these units must be obtained Compilation sheets are made for the pastures or allotments in a manner similar to those for townships Much of the previously determined data can be used, but some areas must be replanimetered. Fig. 90 shows that a fence separates the two largest types into two pastures and that there is a small overlap of each type into the pasture dominated by the other type. The overlapping areas are planimetered and the acreage and grazing capacity in each instance are subtracted from the type and added to the pasture into which the overlap occurs The type figures are then realigned by pastures, and the summation acreage and grazing capacity figures are recorded on the map

The Grazing or Range-Management Plan

The range owner or administrator, like a construction company, must have a detailed plan if, in the long run, management efforts are to be rewarded to the fullest capabilities of the land A reference record of past treatment and of grazing capacity is also desirable

A grazing plan is organized into three sections the written report, the graphic section, and the field-application section (*18, 20*)

Written Report

This part of the plan covers the following points

Season of use, present and recommended seasons

Class of stock, present and recommended, with reasons for proposed changes

Number of stock, present stocking and estimated grazing capacity, stated in animal months If present stocking exceeds the range inventory estimates, specific reductions are recommended

Condition of range, each major unit briefly described

System of use, recommendations, considering number of head and season of use for all units of the range As applied to sheep range, the current system of use is compared with others

Riding, particularly more effective riding on cattle and horse ranges during part or all of the season

Herding, current methods compared with others on sheep and goat ranges

Salt plans, current plan and possible modifications to obtain better livestock distribution, chiefly on cattle and horse ranges

Special management problems, such as deficiency of water supply, rodent damage, poisonous plant areas, and erosion An action program is recommended

Utilization of key areas, by key species and utilization standards for each key species selected for each range type

Forage-acre requirement, the I.A R figures used in computing the range capacity are assembled If further study is needed, areas and methods are recommended

Conversion factor, the ratio of cow months to sheep months is stated where change in class of stock is recommended

Graphic Report

This section contains the composite maps and overlays for each major unit, which depict topography, locations of water, and cultural and other features It also contains the overlays for the base map showing grazing capacities and range improvement proposals The tabular summarizations of the resource and management data are also included

Field-Application Section

This highly practical section is prepared for each allotment in a ranger district, as on national forests, and for each private owner of a surveyed range The section is divided into two parts (1) *the ranger field plan*, which consists of a map of individual allotments, with a transparent overlay that serves as an inspection report form (a new overlay being used annually) and an allotment inspection sheet showing current plan of use together with a record of actual use data as they are collected, and (2) *the rancher's or permittee's plan*, which comprises a map showing the ranch or allotment, with indications of how the different units are to be used The field applications section contains all written and tabulated management proposals in the use of the range

Application of Management Plan

The success of a management plan will hinge largely on three conditions the accuracy of the range survey upon which it is based willingness of the rancher or permittee to cooperate in applying the plan, and the effectiveness of subsequent inspections of results with the application of needed adjustments

Practicability and flexibility are essential requirements of a successful grazing plan An involved, overly theoretical plan is soon cast aside by stockman or administrator Ultimate, if not immediate, financial returns for his management efforts must be apparent.

A grazing plan must be checked frequently in the field, preferably every year Actual use and current utilization records are the basis for grazing capacity and other plan adjustments (*18*) It is of greatest importance to maintain complete and accurate data for these records which themselves are a permanent part of the management plan

Sample Range Survey Management Problems and Calculations

The following problems, with the steps involved in their solution, show how survey data may be summarized and used in management planning.

Problem

A range area consists of 247 acres of open woodland. 27 acres are inaccessible to sheep and 45 acres are inaccessible to cattle. The average density is 0.6, the key plants for cattle are *Poa*, *Melica* and *Lathyrus*, and for sheep they are *Lathyrus*, *Senecio*, and *Cercocarpus*. Forage acre requirements are 0.7 forage acre per month for cattle and 0.2 forage acre per month for sheep.

TABLE 27

Forage Composition	*Composition* (Percent)	*Av. Density*	*P.U.F. for Cattle*	*P.U.F. for Sheep*	*Comp. × P.U.F.* *Cattle*	*Comp. × P.U.F.* *Sheep*	*Den. × P.U.F.* *Cattle*	*Den. × P.U.F.* *Sheep*
20% Grasses								
Poa	5	0.030	0.70	0.60	0.035	0.030	0.021	0.018
Melica	7	0.042	0.70	0.50	0.049	0.035	0.029	0.021
Bromus	8	0.048	0.50	0.40	0.040	0.032	0.024	0.019
40% Forbs (Weeds)								
Lathyrus	10	0.060	0.70	0.90	0.070	0.090	0.042	0.054
Senecio	15	0.090	0.30	0.60	0.045	0.090	0.027	0.054
Pentstemon	10	0.060	0.30	0.50	0.030	0.050	0.018	0.030
Agoseris	5	0.030	0.50	0.70	0.025	0.035	0.015	0.021
30% Browse								
Cercocarpus	5	0.030	0.70	0.80	0.035	0.040	0.021	0.024
Ceanothus	15	0.090	0.20	0.40	0.030	0.060	0.018	0.036
Rhamnus	10	0.060	0.00	0.10	0.000	0.010	0.000	0.006
10% Trees								
Quercus	8	0.048	0.20	0.40	0.016	0.032	0.010	0.019
Pinus	2	0.012	0.00	0.00	0.000	0.000	0.000	0.000
Totals		0.600			0.375	0.504	0.225	0.302

A. Relation between density and composition in calculation of *forage acre factor*. Figures are shown in Table 27. (In practice either the density or the composition of each species would be estimated depending upon whether the square foot density or the reconnaissance method were used.)

Summation (density × P.U.F.) = Forage acre factor
(where square foot density method is used)
0.225 for cattle
0.302 for sheep

or

Summation (composition × P.U.F.) × av. density = Forage acre factor
(where reconnaissance method is used)

Solution

$$0.6 \times .375 = 0.225 \text{ F.A.F. for cattle,}$$
$$0.6 \times .504 = 0.302 \text{ F.A.F. for sheep}$$

B Calculation of *forage acres*

$$\text{F.A.F.} \times \text{Surface acres} = \text{Forage acres}$$

Solution

$$\text{Cattle} \quad (247 - 45) \times 0.225 = 45.5 \text{ F.A.}$$
$$\text{Sheep} \quad (247 - 27) \times 0.302 = 66.4 \text{ F.A.}$$

C Computation of *grazing capacity*

$$\frac{\text{Forage acres}}{\text{Forage acre requirement}} = \text{Grazing capacity}$$

Solution

$$\frac{45.5}{0.7} = 65 \text{ cow-months}$$
$$\frac{66.4}{0.2} = 332 \text{ sheep-months}$$

D Calculation of *conversion factor* from cows to sheep

$$\frac{\text{Grazing capacity for sheep}}{\text{Grazing capacity for cows}} = \text{Conversion factor}$$

Solution

$$\frac{332}{65} = 5.11 \text{ sheep-months per cow-month.}$$

E *Use of conversion factor* If an adjacent, similar range has a carrying capacity of 500 cattle for a 5 month grazing season, how many sheep will it carry for 3 months?

Solution

$$500 \times 5 = 2{,}500 \text{ cow-months}$$
$$2{,}500 \times 5.11 = 12{,}775 \text{ sheep-months}$$
$$\frac{12{,}775}{3} = 4{,}258 \text{ sheep}$$

Range Herbarium

The building up of a herbarium composed of forage, browse, poisonous, and common, unpalatable species is an essential part of a range survey. Since the value of the collection depends on the care with which specimens are selected, dried, mounted, and labeled, an outline for these activities is briefly presented. Complete descriptions of collection procedure are given by Pool (7), Sampson (*11*) and Sanford (*12*).

Each specimen collected must be complete enough to make identification possible. Herbaceous specimens should include root, stem, leaves, flowers, and mature fruit; woody specimens should show a typical shoot, a bark segment, flowers, and mature fruit.

In field collecting, the chief item is a plant press which may be constructed by the collector or purchased from a botanical supply house. The preferable size is 12" x 18". The press consists of eight strips ¾" x ¼" x 16", and ten strips ¾" x 11", of strong wood such as oak, ash, or hickory, in the form of two firmly nailed lattices. Newspaper or, preferably, cut newsprint is used for drying sheets between the absorbent blotters. The press is held together by two belts or straps which permit application of pressure, or, at headquarters, a 50-pound sand bag may be placed on the press. A trowel or pick are convenient tools in procuring specimens.

A field notebook, preferably of pocket size, is needed to record information which is utilized in filling out herbarium cards, similar to the one illustrated in Fig. 91. These cards, with glued surface on the back, are attached to the lower

RANGE-MANAGEMENT HERBARIUM

Name of Institution and Division

Collector's Plant No.________ Herbarium No. ____________

Name ________________, ________________
(Botanical) *(Common)*

Locality________________ ________________
(Elevation)

Type________________ Abundance____________

____
(Habitat and association)

Forage value________________________________
(Cattle, horses, sheep, or goats) *(Forage preference, %)*

________________ ________________
(Season cropped) *(Cropped when mature)*

Collected by________________ Date__________

FIG. 91

right-hand corner of the mounted specimen. The collector's plant number is first recorded in the field book and then placed on the retaining sheet of the specimen. The number is later recorded on the herbarium card when the specimen is mounted.

In pressing, the plant specimen should be arranged so that the flowers and fruit are spread out, to facilitate observation. Plants should be laid out flat and should not be overly crowded. If too long for the retaining sheet, the specimen may be folded in a V or N shape. Slips of manila paper with a slit down the middle are useful for keeping bent specimens from spreading. Plant specimens are best preserved if dried fairly rapidly. To hasten drying, a dry, absorbent blotter is placed on each side of the retaining sheet containing the specimen. These blotters should be changed once a day when the specimens are succulent and about twice a week when the plants are moderately dry. During the drying process the collection should be under sufficient pressure to keep the plants from curling.

Herbarium specimens should be securely mounted The mounting sheets are usually 11½" × 16½" and are made of white, light-weight cardboard The specimen may first be glued in place and then firmly fastened with narrow strips of surgeon's adhesive Heavy specimens may be sewed in place Extra flowers and fruits are placed in a small envelope, which is glued to the mounting sheet The herbarium card or label is affixed to the lower right-hand corner of the mounting sheet

Terms Pertinent to Range Inventories and Grazing Plans

Administrative unit A range area under the specific management policy of a single agency individual or cooperative group of individuals

Animal unit Forage requirements of a mature cow for 1 year Five sheep or five goats are generally regarded as equal to one cow for range grazing

Animal unit months, or A U M Forage or feed sufficient to support a mature cow or its equivalent for a period of 30 days It may be further defined as requiring 300 pounds of total digestible nutrients or the equivalent of 3/10 ton of hay

Base map A map on which data gathered by a range survey is compiled

Carrying capacity, see Grazing capacity

Cow month Feed or forage necessary to maintain a mature cow for 30 days Unweaned calves are included with cows in estimating cow months Cow month also refers to unit of time a given range area is or may be grazed

Culture Man-constructed features shown on a map as distinguished from natural features fences roads etc

Density Percentage of total ground area covered by vegetation preferably expressed as a fraction or in tenths 10/10 = 1 0 or 100 percent density 5/10 = 0 5, or 50 percent density

Drift fence A fence often supplemented by natural barriers for preventing or retarding stock from drifting to an adjoining area

Enclosure An area within which livestock or other specified animals are confined by fencing or other artificial means

Exclosure An area from which livestock or other specified animals are excluded by fencing or other artificial means

Forage acre A hypothetical acre with a 10/10 density of forage that can be utilized to the limits of the physiological endurance of the vegetation Forage acre factor × surface acres = forage acres

Forage acre factor An expression of relative forage value Average density (by type and subtype) of range forage × proper use factor (average weighted palatability) = forage-acre factor

Forage acre requirement The number of forage acres or fraction thereof required to support a mature grazing animal for a specified period without injury to the range resources

Forage value The rank of a range plant or a plant type for grazing animals under proper management, preferably expressed as proper use factor

Grazing capacity The number of animals that can be maintained on a unit area for a stated period of time without injury to the range or other resources *Carrying capacity* is a synonymous term

Grazing (range management) plan A specific grazing program for a private

range or public grazing allotment, preferably based upon range-inventory information. It is usually graphic, accompanied by written directions, and should include the yearlong operation.

Grazing (range) survey. Systematic collection of data pertaining to forage and other resources pertinent to proper range management on a range allotment or management unit.

Grazing unit. Any division of a range used for handling stock. It usually refers to a subdivision within a range holding or a grazing allotment, as on public range.

Intensive grazing survey. A range survey entailing detailed mapping and data, usually including types of 5 acres or less.

Mosaic (photographic). A picture assembled and reproduced from selected portions of photographic contact points.

Overgrazing. Elimination or thinning out of desirable range vegetation, perhaps followed by accelerated erosion and attendant evils resulting from excessive or unseasonable grazing.

Overlay. A transparent sheet used as a supplementary map to show important additional features or information of more or less changeable character.

Overstocking. Stocking beyond the safe grazing capacity.

Permittee. One privileged to pasture a specific number of stock on a public range by reason of having been granted a grazing permit.

Planimetric map. A base map of a specific area showing drainage courses and major topographic features derived from aerial photographs or by other methods.

Plant cover. All plants on an area regardless of their palatability.

Plant density, see Density.

Proper stocking. Stocking of a range to its safe grazing capacity, or slightly below.

Proper use. The degree that range forage may be utilized on a sustained yield basis when all services of the land are considered.

Proper use factor (palatability factor). The percentage weight (sometimes height) at which the available plant species are grazed when the range is properly used.

Proper utilization. Degree of annual removal of forage that will maintain or improve the grazing capacity of a range unit over a series of years; term is synonymous with that of proper use.

Range inspection. The act of examining a range for condition, to discover errors in the existing management, and to gather data for remedial measures.

Reconnaissance. Here applied to grazing surveys in a special sense.

Sheep month. Amount of feed or forage necessary to maintain a mature sheep, or ewe with suckling lamb, for 1 month. *Commonly figured as 1/5 of a cow month.* Sheep month also refers to unit of time a given range area is or may be grazed.

Surface acreage. The acreage contained within the boundaries of a plant type or of other divisions involving a range management plan.

Sustained forage yield. Continuous, season after-season production of a desirable amount and quality of forage under a specific grazing plan or practice.

Type map. A map showing plant types (associations) and their designations. It may also show other range management information.

Type symbol. The numerical symbol numbers adopted to express character of forage for two or more types.

Utilization The extent to which one or more kinds of foraging animals has consumed the current production of forage on a range unit, usually expressed in percentage by height or volume weight of forage removed

Vegetation subtype A floristic unit in a vegetation type (association) which differs in composition, condition, and/or density from the type as a whole

Vegetation type A range area supporting a plant community distinguishable in its botanical composition from other range covers

Yearlong range A range that is suitable for grazing at any or all times in the year, though not on the same land unit

Write up Elaboration of field notes recorded for a plant community taken while making a range survey, includes composition and density, range condition, and important management features

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SOME ECONOMIC, PHYSICAL, AND SOCIAL ASPECTS OF RANCHING

With the knowledge of methods of improvement and management of ranch properties presented in the preceding pages we consider in this chapter some of the economic problems frequently encountered in livestock ranching and ways in which they may be analyzed It is in the main directed to the beginner who is considering buying and operating a ranch

Livestock ranching was formerly regarded as a speculative undertaking Ranchers neither received nor requested assistance in solving their problems Currently the enterprising rancher is primarily interested in operating and rebuilding a more limited tract of land for quality livestock production The operator is therefore interested in such economic and social issues as taxation tariff policies investment and credit, livestock marketing and studies in the biological physical and social fields

A well considered economic research program of grazing lands and ranching methods would directly benefit operators and it would help students of agricultural colleges and others to understand the resources and problems of ranching

Classification of Range Lands

The natural grazing lands are sometimes differentiated according to season of the year in which they are pastured There is spring fall range land summer range land winter range land and yearlong range land (74) These areas occur from the high mountains to low lying desert range The cover may consist of a combination of shrubby growth forbs and grass or essentially of a pure grass stand Yearlong range is most extensive in the Southwest where winter climate is mild Obviously the lowest cost of livestock production is obtained where a reasonably good balance exists between the different kinds of seasonal ranges

General Considerations in Choosing a Ranch

Ranching is a complex industry involving many skills and various forms of labor Familiarity with the factors involved can be acquired only by personal contact with them

Experience

"What factors should I take into account in acquiring a livestock ranch of my own?' 'How should I proceed to find a ranch suited to my pocketbook and to my liking? 'How much money will be required to buy a ranch upon which I can make a living?"

Questions of this nature are frequently asked by young men who desire to buy a ranch and not infrequently by ranch operators who plan to enlarge their holdings Certainly a potential stockman seeking a ranch needs some standards or measures to help him properly appraise its worth In the following discourse are defined and analyzed the standards that should ordinarily be used in selecting a profitable livestock ranch

The most important single factor is the man himself His success will depend largely upon his business acumen and ability to adopt proven economic methods, upon his ambition, fondness for and knowledge of livestock, and upon his enthusiasm for ranch life *(10)*

Purchasing a combination home and operating ranch entails much more careful judgment than buying a ranch purely as an investment The decision to buy a ranch should not be based upon its physical features alone, the personal abilities, financial position and preference for a particular kind of livestock, among other things play a major role

Assuming that a young man has the basic personal requirements and the desire to become a stockman, how can he learn to appraise and operate a ranch? The best and often the only way to acquire adequate practical training is to hire out to a successful stockman In this way the apprentice will learn improved and modern methods of land and livestock management While serving his apprenticeship he should save his earnings engage in all classes of work, and study the reason for doing a job the way it is being done

If opportunity affords the potential stockman may supplement or intensify his training by attending an agricultural college, but no young man should expect to run a ranch successfully on a college education alone Practical ranch experience will teach him how to do things

The use of the local extension service, Federal agencies and libraries

will help him meet important problems Cooperation with these public agricultural agencies will in the long run also pay dividends

Choosing General Location

The factor that most strongly influences choice of a general location is probably the region where one was reared and that one knows about. Personal contacts and previous experience usually influence the decision on the general location of a ranch

Climate is also important If the climate satisfies personal tastes, is reasonably favorable to the production of good forage crops, then, presumably, the climate is satisfactory from a business and personal standpoint.

It is important to select an area where the type of ranching preferred is highly developed To have a yearlong range in Montana is almost impossible, to have a cattle ranch in a predominantly sheep country is unsatisfactory

Selecting the Ranch

Once the general location is decided upon, many factors come into prominence in selecting a livestock ranch These factors may be divided into three categories physical, social, and economic, although, admittedly, the subjects are interrelated in many instances

The most important physical factors are topography, soil, forage, water, and animal and plant pests

Topography This factor plays an important role in the selection of a stock ranch, although less so than in farming Both sheep and cattle can use rough, mountainous ranges but sheep will utilize rougher country more completely than cattle (Chapter 15) The effect of topography on erosion and forage production is also important Usually the most desirable range has gently rolling topography, with nearby mountainous areas supplying abundant fresh water and lush summer forage

Soil. Many a beginner in stock raising has invested in a ranch with poor or eroded soil (*5*) Large and nutritious forage crops cannot be produced on range where the soil has been seriously depleted

The stockman is primarily interested in the forage yield The prudent purchaser appraising the area will take into consideration the past stocking of the ranch, he will consider the amount of vegetation as well as its composition and physical condition, actually and potentially

Forage The stand of good quality forage is of prime importance, since it determines the profitability of a range The character of forage

desired will be largely determined by the kind of animals to be grazed. And the possibility of artificial range reseeding should not be overlooked (Chapter 11). Suitable natural forage should be available during much of the year to hold down the period and cost of yard feeding (*6, 20*).

Water. A ranch without adequate stock water is worth little. Attention should be given to the quantity of water available, its quality, its dependability at needed seasons, and the possibility and cost of developing additional water (Chapter 14). The cost of maintenance may be high, especially in the Southwest, where stock water is commonly stored in reservoirs.

The possibilities of developing irrigable hay or pasture lands should also be kept in mind.

Range Pests. To overcome the presence of range pests is often difficult. The unwitting purchase of a ranch harboring poisonous plants may result in serious consequences. And although predators are becoming less important as destructive agents in the stock industry, in some areas they are still troublesome in sheep production. Local residents are usually familiar with the predator situation and should be consulted.

Rodents (ground squirrels, prairie dogs, gophers) frequently reduce forage supply markedly and deserve local consideration. Rodent infestations are easily recognized by the presence of loose soil or prominent runways around entrances of their dwellings.

Social Considerations. It is especially desirable to select a ranch where the social life is agreeable. The standards of living in the area are often a good indication of the value of the land and of the culture and intelligence of its people. It is better to begin ranching in an area already devoted to the industry, where there are neighbors with whom to cooperate, than to pioneer in a new area where settlement is speculative. Also, the extension service is usually well equipped to give assistance, especially in an area already developed.

The assessed value and tax rate of lands in some regions may be excessive because of high cost of local governments due to inflated evaluation of properties. Hampson (*8*) reported that the taxes on certain grazing lands in South Dakota were higher than the grazing fees on similar government land.

Nearness to roads, rail transportation, schools, churches, and markets have a direct bearing on the net income received and on the cost and standard of living.

Economic Considerations in Choosing a Ranch

Under economic factors are included such considerations as size and physical shape of the ranch use of public or privately owned lands buying or leasing appraising range land values buying the brand (livestock improvements etc), and distributing the capital investment

Size of Ranch

The optimum size of ranch is that which will yield the highest net return for the use of the operator s land labor, capital and managing ability (*15*) The size of ranch meeting these requirements is often spoken of as the economic size The probable returns are more closely associated with numbers of livestock than with range area since carrying capacity varies so greatly The returns per cattle or sheep unit will also depend on the kind of forage general management carrying capacity and breed of livestock The optimum size of ranches in the West seems to lie between those that support 2500 to 5000 ewes or 250 to 600 cattle (*16*) The lower limit of economic size depends primarily upon the number of head that make fur good animal and range husbandry practices Saunderson in 1937 (*15*) defined the minimum sized economic ranch as one that yielded about $1200 annual cash income and which in the Intermountain region, would require about 1200 ewes or 100 to 150 cattle The calculations were based upon average prices of wool lamb and beef In 1950 because of the low purchase power of the dollar the cash yield of the minimum-sized ranch was probably about twice as large as in 1937 For California conditions, Shultis (*18*) reported that 700 to 1000 ewes or about 100 breeding cows were required for average annual family income if the operator was out of debt

The following paragraphs present some theoretical economic concepts which may be of interest and value to those accustomed to thinking along similar lines

The choice of size of ranch and scale of operation depends on (1) the availability of the factors of production such as land, labor capital, and management ability and (2) their organization for maximum efficiency of output of ranch products To understand these relationships the theoretical cost curves of economists are useful These cost curves are conceived for a long run or a short run period In the long run period all the factors of production may be varied in the short run period at least one of the factors cannot be changed in magnitude A rancher who is planning his operation from the beginning will probably operate in the "long run" because he can acquire or dispose of factors of production and can combine them in any manner desired within finite limits. An operator who already has a ranch usually is in the "short run" because one or

more of his factors of production cannot be changed in the period for which he is planning his work, he must, therefore, adapt his plans to the given resources

The so called rancher's 'planning curve," which is an envelope of the short run cost curves of ranch operations of given sizes, is a long-run cost curve [1] The

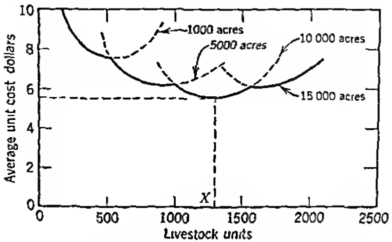

FIG 92 Planning curve for livestock ranches

planning curve (Fig 92) is made up of a series of short run cost curves (Fig 93) and, theoretically, would be of a perfectly smooth U-shape if calculated from an infinite number of short-run curves

The short-run curve (Fig 93) indicates that, for a ranch of given size and combination of other factors of production, some point P exists at which the costs

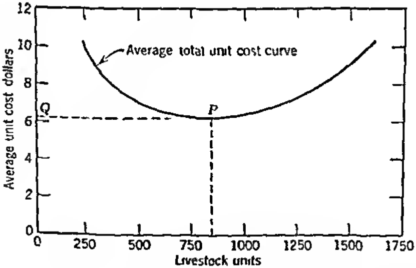

FIG. 93 Theoretical cost curve of a ranch of, for example, 5000 acres

of production per unit head of livestock are at the minimum Any smaller or larger quantity of the other factors of production applied to this ranch would result in increased per unit costs The curve may be recognized as that of diminishing returns" "increasing costs' or variable proportions.

[1] This curve shows the lowest possible average cost of producing any output when the operator has adequate time to make all desired adjustments

If similar curves could be constructed for other size ranch units in the same general area (similar soils, marketing conditions, and other factors of production) a planning curve (Fig 92) could be drawn which would show the optimum combination of all the factors, assuming all can be readily varied An optimum combination is indicated by point X in Fig 92 (10,000 acres, about 1300 head) This long-run curve provides a theoretical basis for selecting the ranch size, amount of capital to be invested, and labor to be used consistent with the managing ability of a given rancher

The planning curve would have much practical value to the ranch buyer provided the data were available for drawing such a curve The information,

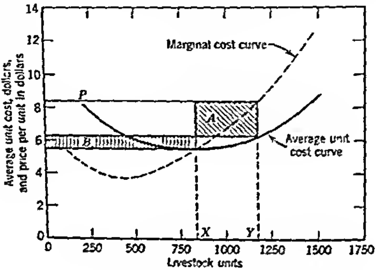

FIG. 94 Curve showing change in profits by producing beyond the point of least cost per unit.

however, is seldom, if ever, available, and the planning-curve concept has value only in providing a framework for logical analysis of the data that can be compiled Observation of existing ranches and discussion with ranch operators, well informed local people, or public officials may provide a basis for classifying ranches in some relative position on a planning curve Such a classification will give something of a "yardstick" in judging advisability of proposed ranch investments

After the optimum ranch has been selected, economic theory uses the short run average total unit cost curve (Fig 93) to indicate the scale at which the ranch should be utilized in producing livestock. To the curve of Fig 93 should be added a price line *QP*, indicating the price per head the rancher expects at the time of marketing, and the marginal cost curve which shows the addition to total cost resulting from increasing the output by 1 livestock unit. The relationship of the three curves, including price line *P*, is shown in Fig 94 The marginal cost curve will decrease to a low point, which is at a smaller scale of output than the minimum of the average total unit cost curve The marginal cost will then increase, the additions to total cost (which the marginal cost curve shows) being less than the average cost per unit of livestock until the output *X* is reached The greatest scale of output—the maximum total profit to the rancher—will be at the output *Y* (Fig 94), because up to that point each additional unit of output

returns more than it cost, price being greater than the marginal cost. Beyond the output Y the addition to total cost exceeds the price received per unit, hence such production is unprofitable. The actual profit realized from producing beyond the point of minimum average total unit cost depends on how much greater the total returns are over total costs for outputs between X and Y, which, in turn, depend on the actual level of prices the rancher receives (In Fig. 94 area A shows the increase and area B the decrease in money returns when operating at output Y rather than X, and A will exceed B only up to the output Y)

The short-run cost curves of Fig. 94 present a theoretical concept which may have considerable practical relevance to ranch operations Ranchers usually will have some estimate of expected prices (P) and costs and will know roughly what output they can profitably produce under the expected price and cost situation The planning period in livestock operations is usually greater than 1 year, and the expected prices and costs may be based on likely trends rather than on prices and costs prevailing currently or in the immediate past. The alert rancher will have some notion similar to this theoretical one and will seek out information on prices and costs to enable him to make the best possible estimates to help his operational planning.

Physical Shape of Ranch

This is usually beyond the control of the buyer. Long, narrow, or "patchwork" ranches are not desired but are commonly found, because of attempts of former owners to control water rights along streams. The different pastures should be fairly accessible to headquarters, to minimize unproductive work (*11*). Generally, the headquarters should be located as near as possible to the center of the ranch and still be on the main highway; and the ranch should generally be divided into as many compartments as there are grazing seasons.

Use of Public or Privately Owned Lands

All the acreage required for optimum size of ranch need not be owned by the operator. Often a large portion of the range is owned either publicly or by private operators, and the rancher pays rent in the form of grazing fees or lease. The amount paid in grazing fees on public land and for leases on private land often amounts to less than the economic rent of the area. It is usually to the advantage of the rancher to secure the use of such lands upon which to graze his stock rather than to own the land (*15*). Therefore, in purchasing a ranch, the buyer should know whether the former owner has grazing privileges on the public domain or other tracts.

Buying vs. Leasing

If the potential rancher has only a small amount of capital to invest, it is usually better to lease the property than to borrow and purchase outright (*12*). By leasing, the rancher has opportunity to determine

whether the returns are great enough to warrant ownership If possible the rancher should lease the ranch with an option to purchase after a specified period

Before purchasing the buyer should investigate the possibilities of obtaining satisfactory financing Usually the best way of getting low interest money is through a governmental agency A rate of 7 percent interest on mortgages will break most ranchers Seldom should more than 5 percent interest be paid (*21*) The size of the mortgage should preferably not exceed 50 percent of the value of the ranch 75 percent is dangerous Whether the rancher has a mortgage or not he is entitled to interest on his investment Size of indebtedness is a tremendously important factor in the stability of a ranch operation

Appraisal of Range Land Values

The value of range land depends solely on its income producing capacity in the long run (*16*) The maximum amount that should be paid for the purchase of a ranch is the capitalized value of the expected net income from the property Some range lands do not produce sufficient returns to leave a profit It is better to leave inferior lands idle than to operate them at a loss Ranching is a business and should be handled as such

Discretion should be used in determining what the average economic rent of a property should be for land may have an inflated value during a boom period or an abnormally low value during a depression One method of taking into account income over time is to assume that future long time incomes will be equal to past long time incomes (*4*) But the range may have been depleted so that future incomes will be lower than those of the past On the other hand a run down poor condition ranch might be built up by proper range management practices and future incomes may surpass those of the past

It is well to keep in mind that the cattle and sheep enterprises have periodic up and down swings as reflected in the numbers of these animals (*1 2 3*) The range livestock business or income cycle should be kept distinct from the land value cycle Land values tend to lag behind income because they are overvaluated when purchased during declining incomes and undervaluated when purchased during rising incomes (*1 14*) The operator who purchases a ranch at the low of the land value cycle has the best chance of survival because of lower interest charges on the investment Usually however sale of ranch properties is sluggish during the low of a cycle since returns are small and investment does not look promising During the crest of the cycle when land prices are inflated the sale of range lands like stocks and

bonds, is active, resulting in wholesale losses and abandonment during the trough of the downswing after the crest.

In purchasing a ranch it is common to use empirical methods as guides, including a combination of the amount of capital available, going prices of ranches of comparable size and condition, and intuition. The use of going prices is a good indication of the value of range lands but is often misleading, because they too will be affected by inflated prices. It is wise for the beginner to lean on an experienced friend or a professional appraiser rather than on his own judgment.

An area should not be overvalued because of some speculative element such as the possible presence of oil, ores, future residential sites, or a grazing permit on a national forest.

Buying Brand

In the exchange of ranch property, the purchaser usually buys the "brand." This includes the range lands, water rights, ranch headquarters, equipment such as corrals, machinery, saddle and draft stock, and such numbers of the herd or band as is agreed to. This form of purchase is generally recommended. An income is realized from the beginning; and it offers opportunity for the new owner to work out improved management plans, since the ranch is self-sustaining. Where the ranch land alone is purchased, considerable time may be required to procure a good grade of animals and the needed equipment. A self-sustaining ranch also may be disposed of much more readily than an underdeveloped one.

Credit Facilities and Title Search

Securing the needed capital to purchase a ranch is highly important, for the property cannot be liquidated rapidly (*9*). Fairly low interest rates on loans are now available through both the Federal government and private organizations (*19*).

Most financial agencies will make or require an adequate appraisal of a property before advancing the loan. If the ranch fails to qualify in any vital way, the thought of purchase should be dropped. The buyer should then look for a ranch that meets all requirements.

The sales commission of a licensed broker, commonly 5 percent of the purchase price, is collectible (*18*). The broker brings buyer and seller together, negotiates price, executes the contract of sale, draws up the escrow, and arranges for the title search and frequently for the financing. The price paid would not necessarily or always be lower by the amount of the commission had the purchase been made without the broker. The validity of the title should be made through a title-

insurance company or an abstracting concern. The cost usually amounts from ½ to 1 percent of the purchase price of the property.

Distribution of Capital Investment

The proportion of fixed capital (money to be invested in lands and improvements) and of liquid capital (money for the breeding stock and feed) is another important consideration in ranch ownership. Often the beginner with limited funds is unable adequately to stock his ranch, thereby wasting forage and decreasing net returns.

The proportion of the investment that should be allotted to land as compared to that in livestock varies widely. On many western ranches three fourths of the capital is invested in land. Where the animals are grazed yearlong on the public domain, most of the capital is invested in livestock.[2] In general it is well to hold as low as possible the investment in land, leaving a large proportion of the capital in working form. However, a certain portion must be invested in fences and improvement work.

It has frequently been recommended that not more than 50 percent of the capital be in fixed investment, although during normal times a ranch with $100 or slightly more invested per animal unit will yield a profit. Fluharty (*7*), studying beef-cattle ranching of California for 1937 and 1938, concluded that earnings would seldom justify an investment much in excess of $125 in land and improvements per animal unit for those years. At that time overcapitalization was a common cause of low income to the ranch operator. Wooden (*23*) also recommended land investment as low as possible in relation to the value of the breeding herd on hand. Shultis (*18*), in 1944, pointed out that where all the land is owned, a California family size ranch of 100 breeding cows or from 700 to 1000 breeding ewes would demand a minimum investment of about $25,000. In 1950 the investment would not be less than $40,000.

Of the 16 ranches in South Dakota studied by Hampson (*8*) in 1933, none that had less than 45 percent of the capital invested in livestock had an income of more than $1000 annually. Those that had less than 30 percent in livestock had incomes of less than $200 annually. In general the proportional ranch investment to be recommended is as follows: 50 percent or less in land, 35 percent or more in livestock, 15 percent or so in improvements.

Many operators keep liquid funds on hand to enable them to take

[2] This proportion is only apparent. If the amount paid in fees or leases were capitalized and this capitalized value used, the ratios considered might be about the same as where the land is owned.

advantage of bargains as they arise A certain kind of livestock may be offered at low prices at a time when the operator is in a position to buy because of excess hay or range forage on hand

Selecting Stock

If the beginner does not buy the animals with the ranch, he must purchase stock separately Cheap, inferior breeding stock may gradually be built up to good animals by using quality sires However, it is usually better to begin with good, young breeding stock than to sacrifice the time required to breed up from inferior stock, even though the purchase price is somewhat higher (*13, 17*)

The rancher always has the alternative of purchasing a few good-quality animals and gradually increasing the number of breeding stock from the offspring he produces However, unless the unutilized portion of the range can be leased to another stockman, the forage may be wasted for the first period of years, and maximum income will be delayed

Marketing Stock

The time of marketing range livestock is primarily determined by the age and condition of the animals and by the supply of nutritious forage

Range stock are marketed when they have attained the growth that the operator believes to be most suitable to his conditions In cattle this varies from vealers to 3-year-old steers, in sheep from prime "hot-house" lambs to light feeders Heaviest marketing takes place in late summer and fall near the end of the flush feed season August to November is the period of continuous livestock movements to market over the West as a whole, but in California the largest numbers of cattle and the winter-dropped lambs are marketed in the spring

The animals are usually sent to the closest market at which there is demand for them Great numbers of feeder cattle and sheep from Montana to Texas are shipped to midwestern market centers in summer and fall, where they are sold to farmers for finishing

Summary

The author is hopeful that the foregoing discussion has made at least two points clear (1) that livestock ranching is a complex business, (2) that there is no simple, short-cut, or infallible way of buying a satisfactory ranch property

Experience in ranching and enthusiasm for ranch life are essential

to success A degree from an agricultural college, although helpful and desirable is no substitute for experience

The first point in buying a ranch is to decide on the general location The climate and the suitability of the region for range livestock production must be satisfactory In choosing the ranch the prospective buyer must be sure that the physical factors—topography, soil forage and water—and the social features are satisfactory Next, he must consider certain economic factors notably size and shape of the land the possibilities of leasing adjoining range, the grazing capacity and condition of the range and its seasonal forage balance, the proportional distribution of his capital in land improvements, and livestock respectively, and finally, where or how the animals are to be acquired and when and where marketed In addition, the operator should endeavor to combine these factors in such a way as to obtain the economic size livestock ranch Due consideration to these factors should be helpful in avoiding error of judgment in the selection of a stock ranch The purchaser who borrows more than about half the value of the ranch under average economic conditions should realize that he is taking a chance on repaying the difference before prices decline (*22*)

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PART 4

PROTECTION OF LAND RESOURCES AND RANGE LIVESTOCK

PROTECTION OF TIMBER REPRODUCTION AND USE OF SHADE TREES AND SHELTERBELTS

Grazing on forest lands is an established practice in many countries, including the United States. This chapter deals with the effects of this grazing on timber reproduction; it also treats of the establishment of shade trees and shelterbelts in the interest of livestock production.

Protection of Timber Reproduction from Grazing Injury

The effect of grazing on timber reproduction has long been a matter of concern. In European forests, ancient grazing rights and mixed ownership of the lands have largely prevented adequate protection of the young timber growth (*4, 16*). But on some of the better sites in various European countries timber reproduction is protected by fencing against grazing animals (*6*).

In the United States the effect of livestock grazing on timber reproduction has been studied in several regions of the West (*13, 21, 36, 37, 41, 45, 48*). These studies have shown that where grazing management is faulty serious damage to tree reproduction is likely to occur.

Factors Influencing Damage to Reproduction

The most influential factors causing damage to timber reproduction on the range are: character of forage, season of grazing, degree of utilization, and grazing-management practices.

Character of Forage. Where forage is limited or unsuited to the animals grazed, timber species that can be browsed throughout their height are subject to serious injury, especially by sheep, goats, and deer. On moderately grazed bunchgrass range in the Southwest, Hill (*21*) noted that sheep heavily browsed 32 percent of the ponderosa pine reproduction up to 3 feet in height. On similar ranges that contained more natural browse and forbs, sheep seriously injured only 10 percent of the reproduction. Since cattle and horses relish bunchgrasses, they do little damage to timber reproduction.

Season of Grazing. Livestock grazing is least injurious to timber reproduction when the forage is tender and reasonably abundant. Young tree seedlings may be seriously trampled by stock early in the spring when the soil is wet and the herbage growth is limited. In the Southwest considerable damage may be inflicted by sheep during the dry summer months where palatable browse and forbs are inadequate. By autumn, tree seedlings are less attractive to stock, because the leaves and stems are more fibrous and resinous (*34*). Measurable damage, however, may be inflicted in late fall and early spring when unseasonable snows cover up much of the herbage.

Degree of Utilization. Regardless of locality, too close range use results in much more damage to timber reproduction than conservative grazing (*13*). The extent of damage increases approximately in proportion to the closeness of the grazing. Many seedlings in the cotyledon stage are destroyed by trampling, but goat and sheep that browse seedlings during their first year's growth on closely used range causes even greater loss. In the Southwest the entire crown is often nipped off and the seedlings killed outright.

Grazing-Management Practices. Close herding of sheep, excessive use of dogs, and bedding several nights in one place are particularly destructive to tree seedlings (*43*). Poor distribution of cattle due to incorrect spacing of water and salt grounds, improper handling, and lack of adequate drift and division fences also account for injury to reproduction. The damage may vary from moderate to fairly heavy on cattle range, and to nearly complete destruction on sheep range up to about 3½ feet in sapling height. Goats are even more destructive than sheep, but both prefer the recognized browse plants to conifers. The bedding-out system of handling sheep and its suitable adoption for goats should be followed to the greatest extent possible (Chapter 15).

Total exclusion of sheep or their replacement by cattle as protection of tree reproduction has seldom been carried out extensively, because of economic complications. But cattle and sheep numbers have frequently been cut gradually on public lands to avoid sudden readjustments by ranchers. Correction of damage lies essentially in proper adjustment of livestock numbers to the grazing capacity of each range unit and in adoption of improved management methods.

Grazing in the Pacific Coast and Northwest Region

The forests of this region—California, Oregon, and Washington (Fig. 95, 1*A*, 1*B*, 1*C*)—consist mostly of cutover Douglas-fir, spruce, and pine.

In northern California, Sampson and Dayton (*42*) noted that Doug-

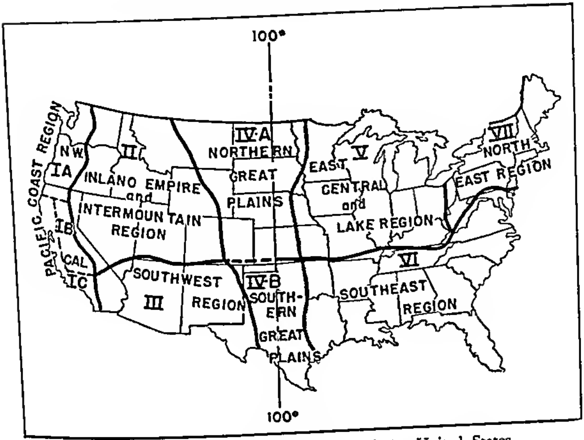

Fig. 95. Forest and planting regions of the United States.

las-fir saplings 2 to 3 feet tall were occasionally broken off by cattle and by deer-rubbing. Cattle browsed seedlings and saplings lightly; sheep and goats browsed more destructively. Sheep preferred reproduction of ponderosa pine (*Pinus ponderosa*), sugar pine (*P. lambertiana*), and white fir (*Abies concolor*) to Douglas-fir. Sampson and Dayton, as well as Ingram (*24*), concluded that *moderate* grazing by cattle and sheep was not destructive to Douglas-fir or associated tree species in this region. They noted that grazing reduced fire hazard and that trampling by stock might aid seedling establishment.

Stockmen in this region sometimes try to increase the grazing acreage by burning and reseeding cutover Douglas-fir lands. The long struggle against brush, timber, and bracken fern is often uneconomical, and most of such areas are best used as timber land (*18, 22*). Equally uneconomical is the conversion to range of the cutover California coastal redwood region. The acid soils of the Douglas-fir and redwood areas are innately forest soils, and forage growth is generally of low quality (*9*). Certainly the redwood lands are ideal for timber production and should be maintained and managed as forest areas.

Grazing in the Inland Empire and the Rocky Mountain Region

The forest region from eastern Washington and eastern Oregon through Montana and Wyoming, and the Rocky Mountain region (Fig. 95, II) are similar in their reaction to grazing.

As early as 1899, Coville (*13*) reported little injury to ponderosa pine seedlings except along trails and on bedgrounds These observations resulted in opening the national forests to sheep grazing But goats were gradually eliminated from the national forests because of their damage to tree reproduction, a decision fully justified according to more recent study (*14*) Ingram (*24*) and Munger (*32*) concluded that moderate cattle and sheep grazing on logged Douglas fir and ponderosa pine lands is compatible with timber growing and fire control in Oregon and Washington

On western white pine (*Pinus monticola*) forest in Idaho, Young and associates (*49*) reported that moderate grazing favored reproduction by planting the seed, but that overgrazing was detrimental to all coniferous reproduction

In mixed Douglas fir ponderosa pine forests of Central Idaho, Sparhawk (*45*) concluded that moderate grazing caused but slight damage to seedlings after they reached 3 years of age Early season grazing was most destructive, ponderosa pine reproduction ranking first in injury, lodgepole pine (*Pinus contorta*) second, and Douglas-fir last

Aspen, after logging, is another species requiring protection from grazing injury in the Rocky and Wasatch Mountains and other forest regions In Nevada and Utah aspen occupies considerable acreage and is used for fuel, posts corral posts, lumber, boxwood, excelsior, and mine props After cutting, there appear great numbers of root sprouts but seldom any seedlings The sprouts are highly palatable to sheep and goats, but are taken limitedly by cattle

Sampson (*41*) found that when aspen is logged, grazing by sheep resulted in destruction of practically all the sprouts by the third year after logging Accordingly, two courses are open exclusion of sheep grazing for three successive seasons after logging, by which time the sprouts are beyond the reach of these animals, or moderate grazing of the area with cattle, since they feed little upon aspen sprouts Sheep may replace cattle in the fourth season after logging Excessive numbers of deer may also destroy young aspen stands (*25*)

Grazing in the Southwestern Region

In this region, embracing Arizona and New Mexico (Fig 95, III), the problem of forest regeneration is essentially confined to some 9,000 000 acres of ponderosa pine stands in the Transition life zone This forest composes about 6 percent of the area and supplies approximately 30 percent of the seasons forage Aridity and frequent droughts cause heavy mortality among young pine seedlings, and good

seed-crop years are rare, hence special land-use practices to favor seedling establishment have been adopted

Hill (*21*) and Pearson (*34, 38*) concluded that ponderosa pine reproduction must be protected from excessive sheep grazing throughout this forest region when the seedlings are young (Fig 96).

(Courtesy of U S Forest Service)

Fig 96 A good ponderosa pine site Left, area closely grazed by sheep for several years in succession contains practically no tree reproduction, right, pasture grazed moderately by cattle and horses supports an excellent stand of pine reproduction Riordan, Arizona

Grazing control is needed where logging is contemplated and where reproduction is being injured on areas not to be cut immediately. Only the rare combination of a good seed year and two or three favorable growth seasons will establish reproduction Under conservative grazing and good grazing management, reproduction does not suffer unduly (*38*)

Recovery of Ponderosa Pine From Grazing Injury. To what extent may pine seedlings, after having been deformed by livestock damage, be expected to recover when protected from browsing? Will they grow into productive trees?

Cooperrider (*12*) reported that browsed off shoots were often replaced within a season on the stubs left and that branches formed

rather normally on naked stems One of the new shoots soon replaced the lost leader, and soon most saplings showed good symmetry.

Pearson (*36*), by first tagging and photographing 87 browsed ponderosa pine seedlings and saplings in Arizona, noted that their recuperation was rapid

> Unless completely defoliated, a young pine has a good chance to come back and grow into normal form, once the damage ceases If severe damage is repeated throughout several years, height growth is checked, and the vitality may be reduced to a point where death becomes inevitable But, after a seedling has attained a height of 4 to 6 inches, only extreme grazing will cause defoliation approaching the danger point year after year Such conditions must be watched on bedgrounds, around watering places, and on other areas of concentration

During the first and second years after germination, seedlings may be killed outright by grazing, because the entire crown is devoured, with no buds left Where reproduction is needed, grazing must be light until the seedlings are at least 3 years old

Relative Returns from Timber and from Forage. On public lands the policy is to interfere as little as possible with established grazing practices, even where returns from the timber are much greater than from grazing

On the Coconino National Forest, Pearson (*35*) in 1927 noted that Federal fees received from grazing were 2 cents an acre annually, whereas the annual increment in a fairly well stocked cutover stand of ponderosa pine was worth 30 cents an acre at average current stumpage rates He concluded

> Translating annual growth of forage and timber into returns to the community, as represented by the f o b selling price of cattle, sheep, and wool on one hand, and lumber on the other, the values are less than $1 00 an acre for the forage crop, and $3 00 an acre for the timber crop In regions where timber grows more rapidly, the differential in favor of the timber crop is still greater The Coconino National Forest has about 600,000 acres of productive and accessible timberland This land is capable of a sustained annual yield of at least fifty million board feet of timber, which will support a permanent lumber industry worth a million and a half dollars a year The livestock industry on this same land, under present conditions, can yield less than half a million dollars a year

But it should be recognized that where the timber is too inaccessible for logging, grazing may be regarded as the primary industry, though not at the expense of injury to watersheds or other resources of the land (*37*)

Grazing in the East-Central, Lake, and Northeastern Regions

These regions embrace most of the hardwood forests of the United States (Fig. 95, V and VII). A considerable acreage of farm woodlands and natural hardwood stands are maintained in this region, chiefly for wood production.

Grazing is not generally economical on these lands. In mixed farm woodlands in southeastern Minnesota, for example, reproduction was lacking or poor where grazing was permitted (*8*). Livestock should be excluded on hardwood stands in this and other areas of the Lake States.

In Indiana, DenUhl (*15*) reported that cattle placed on woodlands soon use up the herbaceous forage cover and then feed largely on the foliage of the younger trees. In a few seasons all reproduction is killed and the lower branches of the older trees are "hedged" up.

In Pennsylvania, Lutz (27) noted that livestock grazing is seriously destructive to the hardwood forest. Direct injury consists of browsing the tops, breaking young trees by rubbing and trampling, and pulling seedlings out of the ground. Livestock should be excluded on farm woodlands where continued wood production is desired.

Deer are also seriously destructive to young woodlands in this region (*11, 23, 39*). Deer browsing has killed many stands of young hardwood, conifers, and palatable shrubs in the New England states, Pennsylvania, and the Lake states. In winter, when feed is limited, deer eat the shoots of many valuable trees. Until the deer herds are reduced in proportion to the supply of winter browse, planting of woodlands will be a poor risk.

Efforts to increase deer browse have failed, because the new plantings are destroyed by the deer before they can be established. Neither is winter feeding of starving deer the cure. Where food is limited, a prolonged open season on both sexes will save more deer and tree growth in the long run than any other procedure.

> The undesirable effects of the deer problem upon attempted forest management have proven equal to those suffered by the deer. Excessive deer herds have in many sections resulted in the complete overthrow of natural forest regeneration and have made forest-planting operations impossible (23).

The outcome of deer control, involving education of the public, is awaited with interest.

Grazing in the Southeastern Region

This forest region, essentially the Atlantic and Gulf Coastal Plains area, includes the states from southeastern Texas to the Atlantic Coast (Fig 95, VI) In 1945 this region supported some 7,500,000 cattle and calves and 1,000,000 sheep (*5*) Most of the cattle are pastured on forest range part of the year, grazing being complementary to timber growing

Cattle grazing in the pine forest is seldom injurious to reproduction, except when green forage is limited Campbell and Biswell (*5*) concluded that the critical period is winter and early spring before much growth has taken place At that time buds of longleaf pine (*Pinus palustris*) and slash pine (*P caribaea*) are likely to be browsed to a damaging degree At other seasons cattle may be more beneficial than harmful to pine reproduction This conclusion is verified by Shepherd, Kaufman, and Biswell (*44*) working in North Carolina

Grazing in the hardwood forest reveals entirely different results from those in the piney woods Many superior hardwood tree species are destructively browsed by cattle For example, in the Appalachian region of western North Carolina, Biswell and Hoover (*2*) estimated the degree of defoliation of 14 hardwoods and two coniferous species on an area that, prior to the study, had not been grazed for several years (Table 28)

Under conditions of the study, a few species of low stature were killed by browsing the first year, others were greatly weakened Trees up to 15 feet tall were destroyed by being "ridden down" and defoliated Killing of the more palatable trees would presumably favor invasions of species not browsed Unfortunately, several of the palatable trees are superior timber species

Studies (*44*) in the mountains of North Carolina essentially verified those reported above Here grazing in the hardwood forest is generally destructive If these lands are stocked strictly in accordance with the amount of palatable herbaceous vegetation, injury to tree growth may be slight, but grazing may not be worth the financial risk (*10*, *27*)

Longleaf pine seedlings and saplings are often damaged by "razor backs" or piney-woods hogs Such damage is heaviest on the less well drained soils around rural settlements, where each animal may destroy between 200 and 400 pine seedlings per day (*30*) Hogs chiefly seek the luscious cortex of the main taproot but often chew off young seedlings at the ground level (*46*) They damage or destroy pine saplings 5 to 15 feet tall Fencing longleaf pine lands with woven wire is the

surest safeguard against injury by hogs. Slash pine reproduction is not damaged by these animals.

Benefits to the Forest from Grazing

Benefits from livestock grazing may occasionally equalize or even exceed the damage by aiding reproduction and reducing fire damage. In the Douglas-fir region of the Northwest, grazing livestock increase reproduction by planting seeds and by decreasing competition

TABLE 28

Degree of Cattle Browsing of Hardwoods in the Appalachian Region of Western North Carolina

Species	*Percentage of Accessible Foliage Eaten* 1941	1942
Yellow-poplar (*Liriodendron tulipifera*)	98	25
Black locust (*Robinia pseudoacacia*)	95	95
Ash (*Fraxinus* spp.)	90	90
Sourwood (*Oxydendrum arboreum*)	90	95
Sweet birch (*Betula lenta*)	80	80
Sassafras (*Sassafras albidum*)	65	65
Flowering dogwood (*Cornus florida*)	50	25
American chestnut (*Castanea dentata*)	20	15
Chestnut oak (*Quercus montana*)	10	5
Scarlet oak (*Quercus coccinea*)	1	1
Black tupelo (*Nyssa sylvatica*)	1	1
Blackjack oat (*Quercus marilandica*)	1	1
Hickory (*Carya* spp.)	1	10
Red maple (*Acer rubrum*)	0	0
Pitch pine (*Pinus rigida*)	0	0
Eastern hemlock (*Tsuga canadensis*)	0	0

with herbaceous plants (*24*). In the Southwest, tree seedlings were generally more numerous after a good seed year on heavily grazed than on lightly cropped or protected areas (*21, 34*); but grazing must be light in the following years or the seedlings will be destroyed. In the southeastern pine forests, trampling by cattle in the autumn aided planting of the seed (*44*); but in Arkansas, winter and spring cattle grazing was destructive to loblolly pine reproduction after a seedfall (*19*). In the hardwood forest of the Midwest, East, and Southeast, grazing is generally hazardous. On pine lands in the Southeast, grazing might be beneficial in preventing invasions of hardwoods.

The greatest benefit to the forest from grazing comes from reducing the fire hazard by removing inflammable vegetation (*5, 20, 29, 34, 44*). Livestock trails and driveways are used effectively as fire lines. On

some forested areas grazing has appreciably reduced the cost of fire suppression

Conclusions of Studies

Studies on forest and woodland grazing have resulted in two sets of conclusions those that apply generally and those that apply only to certain regions

Conclusions of General Application

In some localities faulty grazing has caused destruction of young timber reproduction and deformity of saplings The degree of injury depends on the kind of stock, topographic features, season and degree of grazing, character of forage and the way the animals are handled Goats and sheep are most destructive to coniferous reproduction Goats should be eliminated where reproduction is desired, and grazing by sheep should be light during critical reproduction periods Damage to young trees is unavoidable on much used driveways and trails Where possible, travel routes should be located where timber is sparse or inferior and where they will serve best as firebreaks

Conclusions of Regional Application

In the Pacific Coast, Inland Empire, and Intermountain Forest regions damage to reproduction by livestock grazing is seldom serious where range management is good As a general practice, the forage should be grazed before it becomes dry and unpalatable

In the Southwest where growth conditions are more severe sheep, if they are causing heavy damage, should be excluded from cutover areas until the reproduction is well established This may involve a period of 15 to 20 years Sheep should also be excluded for 2 to 5 years where established reproduction is inadequate but where many young seedlings occur Sheep do not utilize satisfactorily the coarse or harsh bunchgrass range, such as Arizona fescue (*Festuca arizonica*), of this region consequently they will usually browse extensively upon the timber reproduction Their exclusion from such ranges is therefore desirable This kind of range is eminently suited for cattle and horses which injure the reproduction but little

On young, western, coniferous plantations no livestock grazing should be permitted until the trees are well established On aspen lands cattle should be substituted for sheep for about 3 years after clear or heavy cutting

Midwestern eastern, and southeastern hardwood forest and woodlands should generally not be grazed by cattle sheep or hogs if maximum and continuous supplies of wood are to be produced

Shade Trees and Shelterbelts on Stock Ranch and Farm

No ranch or farmstead headquarters is complete without some shade trees and one or more shelterbelts to protect the livestock from inclement weather when in a feedlot or corral. Shelterbelts are also useful along pastures and cultivated fields to minimize the effects of strong, drying winds. Shelterbelts or shade trees located to protect the livestock from direct exposure to storms result in bigger gains from the same amount of feed than on exposed areas (*3, 47*). Also, sale value of the property is enhanced, and considerable returns can be obtained from posts, poles, rough timber, and fuel.[1]

Early settlers in the Great Plains and parts of the Midwest regions planted trees for two special reasons: to make the homequarters more attractive; and to temper the effects of weather for the comfort of man and his animals. More recently the objectives of shelterbelts have been: (1) to ameliorate drought conditions; (2) to protect crops and livestock from severe weather; and (3) to reduce dust storms (*33, 46*).

Climatic Effects of Shelterbelts

The influence of shelterbelts, also called windbreaks, on local climate has been studied mostly with respect to precipitation, air and soil moisture, evaporation, temperature, and wind velocity.

It is doubtful that shelterbelts, or even forests, increase the amount of seasonal precipitation (*26*). Zon (*50*) and others (*40*) have claimed that tree stands do increase precipitation; but since rain gauges give only crude measure of rainfall, absolute comparison of experimental areas has not been possible. But shelterbelts do favor more *effective* use of the precipitation by vegetation through tempering other climatic factors.

Shelterbelts increase the relative air humidity by checking air currents and wind velocity. In hardwood forests of midwestern United States, increases in air humidity ranging from 3 to 12 percent have been reported (*50*). Similar data have been reported for shelterbelts in Siberia (*40*).

The fact that shelterbelts apparently reduce evaporation losses is of great importance, since hot, desiccating winds frequently cause failures of farm and range crops. The protective efficiency varies with wind

[1] Where trees cannot be grown conveniently, or where shade for stock is desired without delay, artificial shade shelters may be built. The roofing, usually of wooden boards laid close together, wood slats covered with straw, or galvanized sheet metal, is placed about 10 feet from the ground on joists supported by heavy posts set securely in the ground.

velocity, height, and density of the trees, and distance of the protected area from the windbreak (1). However, their greatest usefulness seems to be the increased accumulation of snow between the shelterbelts and in the reduction in wind velocity.

Windbreaks cause only small temperature changes—a slight drop in summer and perhaps a slight rise in winter (*50*). Tree-sheltered areas increase the efficiency of feeds ingested by livestock compared with that taken on wind-exposed feeding grounds.

The moderating effects of shelterbelts on weather lie chiefly in reducing wind movement. The effect on wind of a shelterbelt of five or more tree rows may be felt 100 feet or more on the windward side and up to 1500 feet on the leeward side. Protected fields are less subject to wind erosion, they lose less soil moisture, the crops are less subject to damage by high winds, and the yields are higher (*1, 33, 46*).

Establishment of Shelterbelts and Shade Trees

The species of trees most suitable for crop and livestock protection in the different sections of the United States vary according to climate and soil. It is advisable to buy the seedling trees from an agency that produces stock from locally grown seed (*17, 31*). Table 29 lists the more widely useful tree species in each of the seven climatic regions of the United States (Fig. 96). The x's indicate the regions in which each species is well adapted, the letters *A*, *B*, and *C* refer to the divisions of Regions I and IV of Fig. 96. Before undertaking establishment of shelterbelts, however, the landowner should consult with the local state or Federal agency regarding species to use, planting methods, and care of the trees.

Shelterbelts that are established on farmstead or ranch headquarters should be located on the two sides of the buildings and feed lots that are exposed to the prevailing winds, usually the north and west (Fig. 97). Best protection is obtained by placing the inside row of trees not more than about 200 feet from house, barn, and feeding yards. The tallest trees should form the center, and the low, hardy shrubs the outside rows (Fig. 98). Bates (*1*), however, concluded that the maximum conservation of moisture for the benefit of crops is obtained when tall belts with three to five rows of trees are established rather than "heavy" belts such as would result from plantings made according to the demonstration in Fig. 98. This point needs further verification.

Trees should never be planted in sod (*17*). The ground should first be plowed and the young trees should be set out soon after frost leaves the ground. Shrubs may be spaced 4 to 6 feet apart in the rows and trees 8 to 12 feet. Care must be taken to place the seedlings at the

FIG 97 Shelterbelt of pines and hardwoods on north and west sides of farm stead buildings and stock lots affords needed protection from winds (Author's parental homestead Oakland Nebraska)

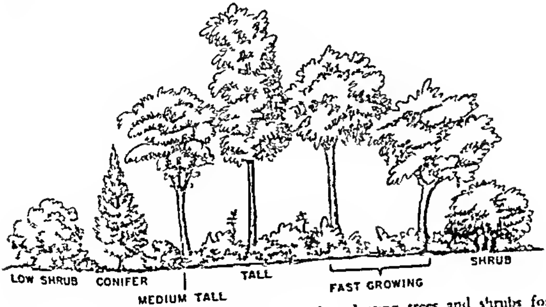

FIG. 98 Desirable cross section arrangement for planting trees and shrubs for best protection against winds.

TABLE 29 (*Continued*)

Tree Species	Region I	II	III	IV	V	VI	VII
Chokecherry (*Prunus virginiana*)				*A*			
Common linden (*Tilia vulgaris*)					*x*		*x*
Cottonwood (*Populus deltaides*)				*A, B*	*x*		
Green ash (*Fraxinus pennsylvanica* var. *lanceolata*)		*x*		*A, B*	*x*		
Honey locust (*Gleditsia triacanthos*)			*x*	*A, B*			
Lombardy poplar (*Populus nigra* var. *italica*)		*x*					
Mulberry (*Morus alba*)				*B*			
Native white ash (*Fraxinus americana*)					*x*		*x*
Norway maple (*Acer platanoides*)				*A*			*x*
Osage orange (*Toxylon pomifera*)				*B*			
Red maple (*Acer rubrum*)					*x*		*x*
Red oak (*Quercus rubra*)						*x*	
Russian mulberry (*Morus alba* var. *tartarica*)			*x*				
Siberian elm (*Ulmus pumila*)	*B, C*	*x*	*x*	*A, B*	*x*		
Sugar maple (*Acer saccharum*) ·					*x*		*x*
White oak (*Quercus alba*)					*x*	*x*	*x*
Yellow poplar (*Liriodendron tulipifera*) ·						*x*	
Tall Shrubs							
American plum (*Prunus americana*)				*A*			
Buffalo berry (*Shepherdia argentea*)				*A*			
Caragana (*Caragana arborescens*) ·				*A*			
Desert willow (*Chilapsis linearis*)				*B*			
English hawthorn (*Crataegus oxyacantha*) (coast)							*x*
Russian olive (*Eleagnus angustifolia*)	*x*	*x*		*A*	*x*		

Shade Trees and Shelterbelts on Cleared Land

In many localities livestock grazing is an important temporary use on cutover forest lands On areas selectively logged, ample trees are left for shade Conservative grazing may be practiced until the understory vegetation is more or less shaded out by the trees, usually involving several years after logging

Fig 99 Desirable spacing of oak shade trees on a cutover cattle range Removal of additional trees would diminish the grazing value of the area Amador County, California

On all forest-cleared areas care should be taken to leave sufficient shade trees for the stock Spreading hardwoods can obviously be spaced wider than conifers (Fig 99) A suitably located shade tree, or clump of trees, for each 8 to 10 cattle, or the equivalent in other animals, is sufficient Where possible, a strip of native shelterbelt trees should be left along at least two sides of the pasture to protect the forage crop and to afford more uniform distribution of snowfall over the area. If too few trees are left the animals may kill them out by compaction of the soil about the roots

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Chapter 21

STOCK-POISONING RANGE PLANTS, THEIR RECOGNITION AND CONTROL

A poisonous plant is one containing a toxic substance which may cause detriment to health or even death of the animal that eats it. When the result is only illness the effect is spoken of as toxic, when death results the dosage is referred to as lethal (*41*). Some plants are mechanically injurious, because they irritate some parts of the body, but these are not classed as truly poisonous plants.

Large numbers of animals die yearly from consuming poisonous plants. Still larger numbers lose in condition and market value. According to Marsh (*24*), poisonous plants account for an annual loss of 3 to 5 percent of all domestic stock grazed on the western ranges of the United States, on local areas the figure may rise much higher. Sheep growers of Wyoming, for example, have estimated their loss at 14.6 percent in some years. The percentage loss is about evenly distributed among cattle, horses, sheep, and goats.

Federal and state agencies recognize the economic seriousness of these losses, yet they seem to be increasing. Stockmen in most instances can prevent heavy losses by maintaining the lands in productive condition, by recognizing the more troublesome poisonous plants, and by keeping the animals off badly infested areas during the most critical period.

The illustrations presented in connection with the discussion of the more common troublesome toxic species and the precautionary measures recommended below should prove especially helpful in minimizing losses from poisonous plants.

Controlling Losses from Poisonous Plants

Grazing animals do not ordinarily eat poisonous plants by choice. Heavy losses are the exception where abundant wholesome forage is available. Accordingly, control of poisonous plant losses lies almost

wholly in the field of range management (*23, 43, 46, 47*). Treatment of plant-poisoned animals on the range is not satisfactory and often not possible. In general, most of the damage to tissues has been done by the time the animal shows symptoms of poisoning.

The following rules should receive due consideration in regions or localities where plant poisoning may occur.

1. Avoid grazing the range beyond its carrying capacity. Remove all animals when the forage crop has been properly utilized (Chapter 17).

2. Avoid too early seasonal use of the range. Early grazing when the forage is still too short to afford a good "bite" is one of the most common causes of losses from poisoning. Such treacherous plants as deathcamas and larkspur often cause exceedingly heavy losses early in the spring when they are most toxic.

3. Do not turn overly hungry animals out on range that harbors poisonous plants. Heavy losses frequently occur when sheep are turned out after being held in a corral for many hours during shearing or when cattle are placed on range after a long shipment. Graze hungry animals on a poison-free area before allowing them on pasture with a scattering of poisonous plants.

4. Drive or herd the animals slowly when transferring them from one part of the range to another and have them well fed before driving them over areas harboring poisonous plants. Cattle and sheep, when grazing quietly, tend to select wholesome food plants.

5. Provide at all times ample salt and essential minerals that are deficient in the local forage. Salt tends to prevent the animals from acquiring a perverted appetite, a condition that may cause them to consume poisonous vegetation. Provide salt in a form that the animals can consume readily. If the forage is deficient in phosphorus or other minerals, provide them in suitable form such as bonemeal. Follow local practice in supplying minerals on the range and provide the animals with plenty of clean water, properly distributed over the range.

6. Do not place salt grounds on poison-infested areas. When watering sheep move the band away from the water as soon as possible, for poisonous plants frequently invade overgrazed areas around waterholes. Select new bedgrounds each season and use them for only 2 or 3 nights at a time; or, better still, use one-night bedgrounds.

7. Eradicate, where practicable, the toxic species by grubbing, frequent cutting, or by the use of suitable chemicals. Eradication by grubbing has proved feasible on areas where the poisonous plants are of perennial growth and occur in well-defined patches. In many instances the livestock saved in a single year have paid for the cost of

grubbing dense patches of larkspur or of pulling waterhemlock from wet soil (*44*). Spraying with 2,4-D or some such selective substance is still in the experimental stage. In Utah 2,4-D proved more or less effective on some species of locos and on waterhemlock, sneezeweed and lupine, but not on tall larkspur, halogeton[1] and milkweed (*46*).

8. Where the cost of eradication is prohibitive or impracticable, fence well-defined patches of poisonous plants to prevent grazing. Such protection greatly favors reestablishment of the forage plants and sometimes results in practically replacing the poisonous species.

9. Graze the kind of stock that is not poisoned by the plants present. Stockmen who have only one kind of livestock should avoid grazing badly infested portions of the range until the most dangerous season has passed.

10. Do not rely on treating poisoned animals as a solution to the poison-plant problem. Yet the help of a veterinarian is definitely desirable where poisoning is critical. Pending technical help, remove the animals to a poison-free area, preferably where the feed is succulent and laxative, such as a fresh alfalfa field.

The Biochemistry and Physiology of Plant Poisoning

Information on the chemical nature of those compounds of poisonous plants that are physiologically active has proved helpful in many respects. A knowledge of what the substance is that produces the symptoms in animals has helped diagnose doubtful cases and develop effective treatment of the animals (*20*).

Although much useful information has been recorded in this field, more is needed, especially as additional plants are added to the poisonous list. Classification of the poisonous properties in plants is complicated because some species may contain several similar poisonous substances or two or more quite dissimilar toxic materials (*19*).

Plant poisons occur both as organic products and as metallic salts, the organic products being the more troublesome.

Organic Poisons

The organic compounds that commonly cause poisoning include certain glucosides, saponins, alkaloids, tremetol, essential oils, resinoids, a few plant acids, and fluorescent pigments.

[1] Halogeton, known botanically as *Halogeton glomeratus* and *H. canescens*, is an annual that was first discovered in 1935 on overgrazed desert ranges in Utah. It now also occurs on ranges of low elevation in Idaho, Wyoming, Oregon, northern California, and Nevada, where losses in spring or early fall, especially among sheep, are sometimes heavy. The poisonous substance is an oxalate, which is largely washed out by late autumn rains, making it less poisonous at that season.

Glucosides These are organic substances which upon treatment with strong acids or alkalis, or some enzymes, yield the sugar glucose and a non sugar compound, usually one related to benzene When the glucoside *amygdalin* is hydrolized the deadly hydrocyanic or prussic acid is released in the plant tissue The enzyme *emulsin* breaks amygdalin down to glucose, benzaldehyde, and hydrocyanic acid The amygdalin glucoside occurs in many species of the rose family (Rosaceae) and in a few species of many other plant families Generally, the enzyme that releases the prussic acid in amygdalin containing plants remains relatively inactive During drought or abnormally low temperatures, however, the enzyme emulsin is activated and may result in a dangerously high content of hydrocyanic acid Cyanogenetic glucosides are the cause of large numbers of livestock losses in many sections of the country

Saponins The saponins are amorphous water soluble glucosides forming colloidal solutions They produce and stabilize emulsions of fats and oils

Many plants containing saponins are toxic Among them are bitter actinea (*Hymenoxys odorata*), pingue (*H richardsonii* var *floribunda*), and species of nightshade (*Solanum*) Digitonin of purple foxglove (*Digitalis purpurea*) a well known heart stimulant, is a typical complex cyclic saponin The property of these compounds to dissolve fatty substances appears to account for the destruction of the red corpuscles and for reducing coagulation of the blood

Alkaloids These are complex cyclic compounds containing nitrogen and having an alkaline reaction They occur most commonly in such troublesome range plants as the larkspurs (*Delphinium*), lupines (*Lupinus*), waterhemlocks (*Cicuta*), deathcamas (*Zigadenus*), and some species of locos (*Astragalus*) Alkaloids have been isolated from plants belonging to more than 50 families of which three fourths are herbs and one fourth are woody plants Not all alkaloids are poisonous Some of the more familiar alkaloids are *quinine* from the bark of the cinchona tree *nicotine* from tobacco *strychnine* from seeds of *Strychnos nux vomica*, and *caffeine* from coffee and tea Most alkaloids have a pronounced physiological effect on animals Several have therapeutic value

The physiological function of alkaloids in plants if any, is not known but they are probably not involved in processes of broad importance They appear to be by-products of nitrogen metabolism in the plants containing them

Tremetol After many years of study a toxic substance called tremetol an oily alcohol was isolated from plants that caused trembles

in livestock and milk sickness in man These diseases appeared during colonial times and have long baffled the medical profession (*20*) Milk and butter are the carriers of the disease from cattle to man In the eastern states white snakeroot (*Eupatorium rugosum*) is the poisonous plant involved in the Southwest rayless goldenrod (*Aplopappus heterophyllus*) is the cause of this peculiar disease

Essential Oils and Resinoids A large number of plants contain the rather indefinite substances occurring singly or in combination known as essential oils and resinoids some of which cause livestock poisoning Various ericaceous plants contain the highly toxic andromedotoxin which is the active principle in the azaleas rhododendron and perhaps the laurels Also the extremely toxic principle of species of waterhemlock (*Cicuta*) is of this category (*20 32*)

The essential oils are volatile and impart a distinctive aroma to many plants hence they may either attract or repel the animals The essential oils are not oils in a chemical sense They are grouped into two categories The terpenes which are hydrocarbons with the general formula $C_{10}H_{16}$ constitute the one group and alcohols aldehydes and keytones which contain oxygen compose the second group

The resinoids appear to be oxidation products of terpenes of little known chemical constitution The physiological function in plants of the essential oils and resinoids if any is unknown They are apparently by products of metabolic plant activities

Organic Acids Certain organic acids occur in sufficient concentration in some plants to cause livestock poisoning the most important being oxalic acid It is a carboxylic acid which is widely distributed in the plant kingdom occurring both in the free state and in combination with potash and lime soda Various cases of poisoning have resulted from stock grazing on plants containing large amounts of oxalates notably in greasewood (*Sarcobatus vermiculatus*) dock (*Rumex* spp) and sheep sorrel (*Oxalis* spp) Oxalic acid acts principally on the central nervous system and on the mucous membranes (*40 41*)

Fluorescent Pigments Several plant products of widely diverse chemical nature are harmful to range stock having light (unpigmented) skin (*16 28 45*) St Johnswort (*Hypericum perforatum*) a well known toxic pigmented plant that is common on the West Coast in western Europe and Australia contains two physiologically active pigments hypericin and hypericum red Typical injuries to animals exposed to normal sunlight, that have consumed plants containing such active dyes are blistering of the light colored areas of the skin inflammation swellhead and sometimes open sores Fluorescent pigments react in the presence of light energy If the light is screened

out, as by pigmented skin, or by application of henna or tobacco juice—an ancient custom in Arabia where St Johnswort caused dermatitis among horses—the plant pigments are harmless

In the Southwest, agave (*Agave lechequilla*) and sachuiste (*Nolina texana*) have caused photosensitization (*47*) Several other plants have accounted for similar symptoms in the United States and elsewhere Fortunately, most fluorescent-pigmented plants are of low palatability, hence they cause minor death losses on properly managed areas

Inorganic Poisons

Any metal if taken in excessive amounts may cause illness in animals In recent years metallic poisoning has become widely recognized, chiefly because of livestock losses from selenium (*4*, *48*), and less commonly from molybdenum, but only occasionally from arsenic

The selenium metal is prevalent in some soils, often in only 1 or 2 parts per million in the soil solution, but some plants accumulate enough to kill animals, including man Wild aster (*Aster commutatus*), salt-bushes (*Atriplex* spp), winterfat (*Eurotia lanata*), some locos (*Astragalus* spp), and species of *Stanleya* and *Mentzelia* may accumulate deadly amounts of selenium (*21*)

Selenium poisoning occurs both in a chronic and an acute form Chronic impairment, called "alkali disease," occurs chiefly in western South Dakota, Wyoming, and northern Nebraska The disease is characterized by loss of hair and by deformity and sloughing of the hoofs (2) Advanced cases will not respond to any known treatment Acute impairment is characterized by partial or complete collapse accompanied by driveling, impaired vision, and loss of appetite It usually results in death in a short time Animals do not acquire tolerance to selenium The disease is cumulative Administration of bromo benzene stimulates excretion of the poison Many range animals have been lost in various localities in a few hours

Molybdenum, in contrast to selenium, is a necessary constituent of plants but neither of these metals is essential to the health of animals More than a trace of molybdenum in the soil solution of pasture lands may cause livestock losses On irrigated pastures of California, notably those seeded to legumes, cattle in some localities have shown symptoms characteristic of molybdenum poisoning (*5*) There is much scouring, rapid emaciation, and marked change in coat color Excessive molybdenum has been noted in the feces of emaciated animals Removal of the affected animals to dry, nonleguminous pasture is usually followed by recovery, though the victims may be permanently stunted Young growing cattle are the most susceptible, but in England mature cattle

have also been affected. Apparently only ruminants are susceptible. Large doses have been fed to horses and hogs without apparent effects.

Other metals such as tin, manganese, and copper have been reported to occur in some range plants in Wyoming in sufficient concentration evidently to impair vision in cattle, causing "blind staggers" (*21*).

Physiological Reactions of Plant Poisons

Plant poisons rarely affect a single animal organ or a single system; rather, most or all body tissues may be injured. Hydrocyanic acid poisoning, for example, inactivates respiration and affects all tissues with which it comes in contact. Organs that function in excretion may accumulate higher concentrations of the toxic substances than the rest of the body and consequently may be more seriously affected. The liver, kidneys, nervous system, and certain other vital organs are often most seriously damaged. Strong acid and alkali poisons are corrosive and destroy local tissue.

The toxicity of a poison depends in part upon the relative rate at which it is absorbed and eliminated. Volatile poisons, like prussic acid, are rapidly absorbed and speedily excreted, hence animals recover rapidly from nonlethal dosages. Slowly soluble substances are absorbed gradually, quickly soluble substances rapidly. Therefore, a toxic plant substance may be only mildly or not at all poisonous in one form or stage of plant growth, and virulently toxic in another. The lungs, skin, kidneys, liver, the mucosa of the alimentary canal, and milk glands, all function in the elimination of poisons. If a poison is absorbed readily and eliminated slowly, it is said to be a cumulative poison.

The toxicity of a particular plant species varies with the habitat, its growth stage, and the part eaten. The leaves of the tall larkspurs may be very toxic when young but lose much of their toxicity after the plant blossoms, but the seeds, which are rarely consumed, are quite poisonous. The rootstocks of waterhemlock are far more poisonous than the tops (*22, 24*).

The susceptibility of an animal to poisoning also varies. Thus larkspur causes poisoning among cattle but not among sheep. Both cattle and sheep are poisoned by deathcamas, but sheep suffer much the heavier losses, because they find these plants more palatable. The foraging habits of animals ordinarily protect them from many poisonous plants. Marsh (*24*) found that horses can be killed by larkspur, but on the range they seldom if ever take a lethal amount. Animals in good flesh are seldom poisoned when grazed on good range. The age of an animal often influences its susceptibility to poisonous plants. Large or older animals are usually more resistant to poison than small

or younger ones, as measured by total dosage, but the toxic dose per unit weight may be larger in the small animals, especially when the difference in size is chiefly due to fat Diseased or starved animals are usually less resistant than those in good condition, and females are frequently more susceptible than males Exertion and excitement increase susceptibility to poisons

Resistance of animals to poison may be classed into *tolerance* and *immunity* Tolerance is the inherent capacity to endure poisons Natural tolerance may be due to conditions that impede dissolution and absorption of poison, to the capacity to effect chemical changes in the gastro-intestinal tract, or to the degree of activity in the fixation, modification, and elimination of poisons (*17, 19*) Some degree of tolerance may be achieved by a protective diet of abundant, wholesome forage (*23*)

Immunity is a term primarily applied to the resistance of animals to infecting organisms The term is generally applied to resistance against the toxic effect of a foreign protein within the animal body Relatively few plants produce poisoning as a result of plant toxins, apparently none of the native poisonous plants on the range do Castor bean (*Ricinus communis*) and black locust (*Robinia pseudoacacia*) are exceptions If a small quantity of the toxin of these plants enters the blood stream and some time is allowed to elapse before a second such exposure, the animal will undergo severe shock (*41*) But, if the first small amount of the toxic protein consumed is followed several hours later, let us say, by a series of dosages at corresponding time intervals, the blood serum will precipitate the foreign protein This reaction will protect the animal from injury through the building up of antibodies between dosages

can vomit.[2] Diuretics may also aid in recovery. Strong tea may be used to precipitate *alkaloids*. *In addition, there are specific antidotes* for counteracting the effects of some plant poisons.

The Primary Poisonous Species

More than 500 species of poisonous plants occur in the United States. According to Dayton (*8*) the four families embracing the greatest number of toxic species are, in order: pea, legume, or pulse family (Leguminosae), buttercup family (Ranunculaceae), composite or sunflower family (Compositae), and the spurge family (Euphorbiaceae).

Of the many species involved, relatively few inflict serious livestock losses. The plants that take perhaps the heaviest annual livestock toll in the United States are species of the following groups: loco or crazyweed, larkspur, lupine, deathcamas, St. Johnswort (also called Klamath weed), waterhemlock, rubberweed, sneezeweed, milkweed, greasewood, goldenrod, horsebrush, and certain prussic acid plants. The following accounts present the more salient facts pertaining to these plants.

Loco (*Astragalus* AND *Oxytropis*)

These are undoubtedly the most destructive poisonous plants on the western range. Each year they kill large numbers of cattle, horses, sheep, and goats. The heaviest losses apparently occur in the Great Plains and Rocky Mountain regions.

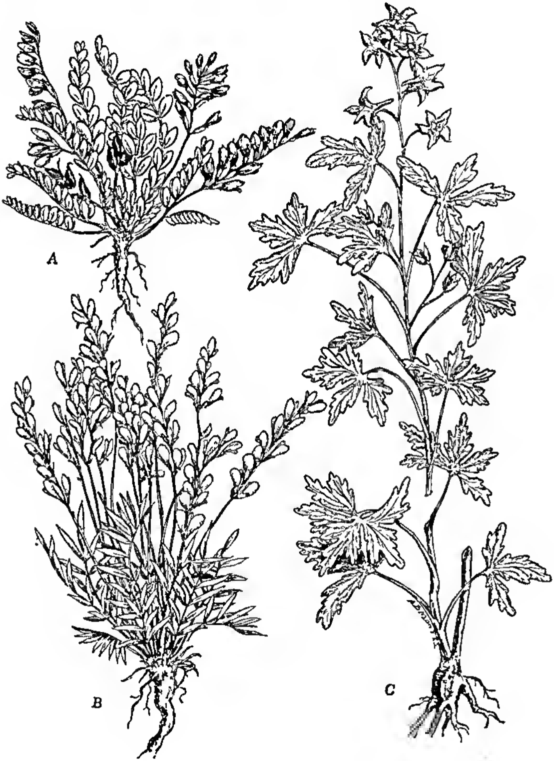
Loco plants occupy all life zones and various habitats from dry deserts and grassy foothills to open mountain lands. The name "loco" meaning crazy, is of Spanish origin.

The species of *Astragalus* and *Oxytropis* are perennial herbs belonging to the pea (Leguminosae) family. They are closely related genera, differing only in the keel of the flower, which in *Oxytropis* is prolonged into a distinct beak. Although many members of these genera are poisonous, three species are especially dangerous (*24*). They are: purple or woolly loco (*Astragalus mollissimus*) (Fig. 100*A*), which occurs from South Dakota and Mexico westward to Wyoming, Colorado, and Arizona; white loco, rattleweed, or crazyweed (*Oxytropis lambertii*) (Fig. 100*B*), which grows from western Minnesota to Montana and southward to Arizona and Mexico; and blue loco (*Astragalus diphysus*), which is most common in western New Mexico, Arizona, and western Nevada. In California, woolly-leaved loco (*Astragalus leucophyllus*) (Plate 1*C*) is one of the most troublesome species.

[2] Horses and other equine species do not vomit. Ruminants—cattle, sheep, goats—can eliminate irritating substances from the stomach by vomiting but rarely do. Vomiting is common among cats, dogs, and hogs.


A
B
C
D
E

Loco plants can poison animals in various ways. Some are highly poisonous and cause death in a short time; others must be eaten over a long period before they cause illness or death. Some species of *Astragalus* absorb selenium when they grow in seleniferous soils, often



A B C

in concentrations strong enough to produce 'blind staggers' and "alkali disease" in range stock (*21*) Animals poisoned by such plants may die in a short time

The more typical symptoms of loco in horses and cattle, though less pronounced in cattle, are dullness and weakness, dragging of the feet, a jerky and uncertain gait, shaggy coat, poor eyesight, nervousness and peculiar action, shying at familiar objects, and constipation Locoed horses are dangerous to ride The symptoms in sheep are much less marked The poison is cumulative

Poisoning is most common in early spring where grazing is permitted before much growth has been produced Keeping the range in good condition and having ample palatable forage at all times is the most feasible means of coping with the locoweed problem Some locos are habit forming, and diseased animals should be removed from the range before they induce other individuals to eat these plants The affected animals should be placed on succulent laxative feed and marketed when in a proper state of flesh

Larkspur (*Delphinium*)

Larkspur kills more cattle on western mountain ranges than any other genus of plants except the locos Only a few instances of poisoning have been reported from the eastern states Larkspurs belong to the buttercup (*Ranunculaceae*) family and when in bloom are readily recognized by the conspicuous spur of the upper sepal of the flower The colors of the flowers vary through shades of violet, blue, and purple Two categories are customarily considered tall larkspurs and low larkspurs

The tall larkspurs grow from 4 to 8 feet high and commonly occupy moist sites throughout the western mountains, where they often form dense stands They bloom during the summer months and do not die down until they are broken by early autumn snows The leaves of tall larkspurs lose much of their poisonous properties after the flowers appear (*1*), hence poisoning occurs in the spring and early summer (*34*) Tall larkspurs are exemplified by *Delphinium barbeyi*, a widely distributed mountain species (Fig 100C), and by larkspur (*D Californicum*, Plate 2*B*)

The low larkspurs, which grow from a few inches to 2 feet tall, occupy a variety of habitats and occur in lesser density than the taller forms (*10*) They appear in the spring immediately after the snow recedes and grow more rapidly than the grasses The blossoms appear early in the season, and the plants are dried up by midsummer, consequently, most poisoning by low larkspurs occurs during the spring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B
C
D
E

months up to June, despite the fact that they remain mildly poisonous well after maturity. This group is exemplified by Menzies larkspur (*Delphinium menziesii*), a highly poisonous species (Plate 2*A*), common over an extensive region from British Columbia and Alberta southward to California and New Mexico.

Both groups of larkspurs have the same toxic principles, namely, delphinin and other similar alkaloids. The amount of larkspur a cow must consume to cause death depends on the developmental stage of the plant.

The first symptoms of larkspur poisoning are sudden falling, followed by intensive struggling. If the dosage is not lethal the animal will rise in a few minutes and walk away without showing further effects. In lethal cases the animal will fall repeatedly. This is followed by prostration, vomiting, and death.

To prevent larkspur poisoning, the larger areas containing scattered stands of these plants may be fenced. Smaller patches may be grubbed out. Sheep are not affected by larkspur poisoning and are sometimes employed to graze off infested areas (37). The danger of cattle poisoning is greatly reduced if grazing is deferred until the plants have bloomed.

LUPINE (*Lupinus*)

Lupines are members of the pea (Leguminosae) family. It is a large genus, and the species are not easily distinguished one from another. They are mostly herbaceous and may be recognized by the alternate and palmately compound leaves, by the butterfly-shaped corolla, as in the sweet pea, and by pods that are several-seeded. They occur commonly throughout North America.

Not all species of lupine are poisonous, but all should be regarded with suspicion until known to be harmless. Some rank fairly high as forage. Lupine poisoning mostly affects sheep, but occasionally also cattle, horses, goats, and hogs (35). Most losses occur in late summer and fall, since the seed-filled pods, which are then fully developed, are particularly toxic (7, 44).

Grassland lupine (*Lupinus laxiforus*) is a good representative of the genus (Plate 2*E*). It occurs from Montana and British Columbia southward to Arizona and California, where, in many localities, it forms rather dense stands.

The toxic substances in lupines are alkaloids, mainly lupinin and lupinidin (35). These substances occur throughout the plant but are most concentrated in the seed pods.

The most conspicuous symptoms of lupine poisoning are labored

breathing and later coma While still conscious a poisoned sheep will usually froth at the mouth and run about in a frenzy, butting against any available object In lethal cases the animal goes into convulsions with legs extended rigidly

The best way to control losses is to keep the animals away from areas known to harbor poisonous lupines, especially after the seed pods have formed, and to provide plentiful wholesome feed

Deathcamas (*Zigadenus*)

These plants belong to the lily (Liliaceae) family They are slender, grasslike herbs, with smooth, mostly basal leaves, erect stem 4 inches to 3½ feet high, and fibrous bulbs that are situated 2 to 8 inches in the soil The small, greenish or yellowish white flowers are borne on racemes 3 to 10 inches long Meadow deathcamas, pictured on Plate 2D, gives a clear idea of the appearance of these plants

Although numerous species of deathcamas occur in the United States, their importance as poisonous plants is restricted largely to the region through the Rocky Mountains westward to the Pacific Coast (*40*) Death losses from the plant are small for cattle and horses but often heavy among sheep, notably in California Oregon, Nevada, Utah, Colorado, Montana, and Wyoming (*3, 9, 22, 25, 27, 33*)

The more conspicuous symptoms of poisoning by deathcamas are frothing at the mouth, nausea with vomiting, nervousness, great weakness, and finally collapse of the animal A sheep may lie for hours or even days before dying The poisonous substance is an alkaloid, zigadenin A relatively small quantity of the plant will kill a sheep

The best way to minimize losses is to prevent sheep from eating lethal quantities of the deathcamas Too early seasonal grazing and too close cropping are associated with heavy sheep losses Eradication of these plants is not practicable Herding sheep away from infested areas and grazing such units with cattle are possible solutions

St Johnswort (*Hypericum perforatum*)

Although St Johnswort is not widespread, it is included with the primary poisonous plants in order to typify a distinctive though small group of toxic species

St Johnswort—called Klamath weed in California—is a European exotic that causes photosensitization and dermatitis in animals having white or unpigmented skin Cattle, horses sheep and goats when feeding upon St Johnswort during bright sunny days are affected, chiefly up to the blossoming stage of the plant (*28*) Because this weed is not highly palatable it causes few deaths The chief losses consist

of the low condition of the animals affected and the crowding out of the better forage plants (*45*).

St. Johnswort belongs to the St. Johnswort (Hypericaceae) family. It is an erect perennial 1 to 3 feet high, with runners at the base. The leaves are stemless and oblong. The flowers are yellow in cymose clusters, the petals, as well as the leaves, having black, glandular dots near the margin (Plate 2C). This weed has spread over extensive areas in California and Oregon, and smaller infestations have appeared in Idaho and some adjoining areas. It occurs in lesser abundance in the eastern states.

The toxic principle is caused by two fluorescent substances, hypericin and hypericum red. In addition to being afflicted with dermatitis, affected animals develop a rapid pulse and respiration, high temperature, and a tendency to diarrhea.

Prevention consists of reestablishing the forage cover of infested ranges. This may be accomplished by conservative cropping and rotation grazing, spraying infested lands with boron or sodium chlorate or other suitable herbicides, and by biological control with insects, followed, perhaps, by reseeding on the stronger sites. The initial experiment in this country of controlling a noxious range weed with insects was undertaken in 1944, when the University of California imported from Australia two plant-attacking beetles, *Chrysolina hyperici* and *C. gemellata*. The original Australian stock was imported from western Europe. These beetles feed exclusively upon St. Johnswort. To date, in California, their destruction of small patches of the plant is impressive. However, a few years before the beetles were introduced the older and denser stands of St. Johnswort were declining conspicuously. This succession has strongly favored reestablishment of California oatgrass (*Danthonia californica*) and other perennial forage plants. Although the introduced beetles are hastening control of this plant, its decline through the phenomenon of natural succession, after a half century of extremely vigorous growth, appears to be the primary factor in its decline.

A safe precaution is to avoid grazing the infested range heavily, especially with sheep, until St. Johnswort plants have blossomed, after which they are of low palatability.

Waterhemlock (*Cicuta*) and Poisonhemlock (*Conium*)

The waterhemlocks are the most poisonous, but not the most destructive, plants in North America (*6*, *32*). They are widely distributed along streams and in marshy places throughout the United States. Losses are chiefly among cattle (*15*). Waterhemlock is highly poison-

ous to sheep, but these animals sustain few losses, since they avoid grazing upon wet or marshy lands

The waterhemlocks belong to the parsley (Umbelliferae) family They are branched perennials with hollow stems 2 to 6 feet high arising from rootstocks The rootstocks have a central hollow space divided by cross partitions that form distinct chambers The small, white flowers are in compound umbels Douglas waterhemlock (*Cicuta douglasii*), pictured in Plate 1*A*, gives a clear idea of the appearance of these plants

Waterhemlocks are poisonous throughout the year In the spring the young leaves and stems are virulently poisonous Later, the above ground parts become relatively harmless, but the roots and rootstocks remain highly toxic Losses are common where cattle trample out and eat the rootstocks or when the operator digs or pulls out these plants and leaves them to dry where cattle can eat them (*14, 36*)

The toxic substance of waterhemlock is a brown, resinoid substance called cicutoxin Poisoning is characterized by violent convulsions and frothing at the mouth In the early stages of poisoning there is twitching of the muscles and quivering of the lips This is followed by champing of the jaws, grating of the teeth, and continued convulsions When a lethal dose is eaten death ensues within a short time

The best means of controlling losses from waterhemlock is to pull or dig out the plants and burn them Eradication in this way is not too difficult or expensive, since these plants are confined to moist patches

Poisonhemlock (*Conium maculatum*), a plant closely related to waterhemlock, occupies well-drained soils Although it is poisonous to all kinds of livestocks its toxicity is milder than in the waterhemlocks (*44*) The tall, hollow stems which have conspicuous purple spots, and the disagreeable mouselike odor of the herbage, readily distinguishes poisonhemlock from waterhemlock (Plate 1*B*) The poisonous alkaloid coniine causes loss of appetite, bloating, salivation, bodily pain, and feebleness There is relatively little danger of livestock losses from poisonhemlock where a good forage cover is maintained

RUBBERWEED (*Hymenoxys*)

Two species of rubberweed cause relatively large annual losses of sheep and, to a lesser extent, of cattle and goats These plants are bitter rubberweed (*Hymenoxys odorata*), to which the name *Actinea odorata* has been misapplied, and Colorado rubberweed (*H richardsonii* var *floribunda*), mistakenly called *Actinea richardsonii* They are members of the sunflower (Compositae) family

Bitter rubberweed is a many-branched annual herb with purplish basal stems, alternate, glandular-dotted leaves which are aromatic and have a bitter taste, and numerous bright yellow flowers (Fig. 101*A*). It grows from Kansas to Mexico, westward to California, most abundantly on overgrazed ranges.

Although bitter rubberweed is of low palatability, sheep will consume enough of the plant on overutilized range to cause numerous deaths. The symptoms are loss of condition, poor appetite, abdominal pain, a green discharge from the nose, frothing at the mouth, and bloating. About the only practical measure of control is to build up the forage stand and avoid too close grazing.

Colorado rubberweed, also called pinguc, is a perennial herb with conspicuous golden-yellow, asterlike flowers of a distinctive odor (Fig. 101*B*). In southern Colorado, northern New Mexico, and the Edwards Plateau region of Texas, sheep losses from this plant are frequently heavy (*18, 24, 42*).

The symptoms of poisoning are remarkably similar to those described for bitter rubberweed. Losses from this plant are probably never serious where the animals are properly handled and the range is well managed. Animals showing poisoning symptoms of either one of these rubberweeds should be removed from the range and placed on a clean area of ample forage.

Western Sneezeweed (*Helenium hoopesii*)

The danger of western sneezeweed on the range is confined to sheep, though cattle may occasionally be poisoned (*31*). Western sneezeweed causes "spewing sickness" in sheep, a disease that sometimes entails heavy losses. The plant is a stout perennial belonging to the sunflower (Compositae) family. It grows 2 to 3 feet tall and has thick, dark-green leafage. The flower disk is a brownish orange, and the ray flowers are orange (Fig. 101C). The plant occurs from western Montana to Oregon, south to California and New Mexico. Especially heavy stands are found in central Utah. The elevational range is between 7000 and 10,500 feet.

The poisonous substance is a glucoside, dugaldin, which in sheep causes depression, salivation, bloating, weakness, nausea, diarrhea, and vomiting. The poison is cumulative, its effects being apparent for a long time.

Preventive measures consist of grazing lightly upon moderately infested areas and of excluding sheep from heavily infested ranges. The herder should be taught to recognize the plant and to use the one-night bedground system and open herding.

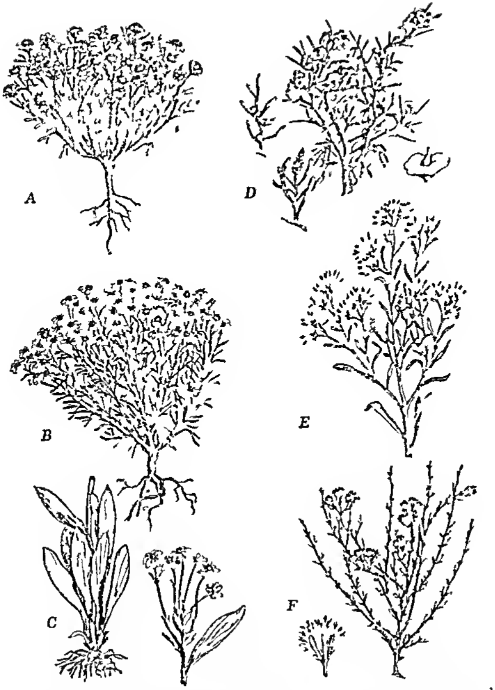

FIG 101 *A*, Bitter rubberweed (*Hymenoxys odorata*), *B*, Colorado rubberweed (*Hymenoxys richardsonii* var *floribunda*), *C*, western sneezeweed (*Helenium hoopesii*) *D*, greasewood (*Sarcobatus vermiculatus*), *E*, rayless goldenrod (*Aplopappus heterophyllus*) *F*, horsebrush (*Tetradymia glabrata*)

Milkweed (*Asclepias*)

The milkweeds have caused heavy livestock losses in many local areas. The losses have been heaviest in sheep, but cattle are also poisoned.

The plants belong to the milkweed (*Asclepiadaceae*) family, the species of which have milky juice. There are two distinct forms of milkweeds: the whorled milkweeds, having narrow leaves which are arranged more or less in whorls, and the broad-leaved milkweeds. Several species of both growth forms are highly poisonous (*26, 30, 44*). In Plate 1*D*, the whorled, narrow-leaved group is exemplified by Mexican whorled milkweed (*Asclepias mexicana*). This species occurs from Idaho to Washington, southward to Mexico. Plate 1*E* shows a broad-leaved form, exemplified by woolly-pod milkweed (*Asclepias eriopoda*). This species is common in California and extends southward into Lower California. Both forms occupy rather dry, hot sites of low to intermediate elevations, but they will also grow in moderately moist, well drained soils. Horsetail milkweed (*Asclepias galioides*) is found in Colorado, Utah, and New Mexico, extending into western Texas. It is poisonous to all stock and has caused serious losses of sheep.

The poisonous principle in milkweeds is a dark, resin-like substance of unknown identity. It is not destroyed by drying, and hay containing appreciable quantities of milkweed is a frequent source of poisoning.

The first symptoms of milkweed poisoning are depression and staggering. The animal has no appetite, and the pulse is high and weak. In many cases spasms occur, followed by rising temperature. Symptoms appear a few hours after the plant has been eaten. Fortunately, milkweeds are not relished by livestock, and poisoning can be avoided if abundant wholesome food is available. Because of extensive rhizomes milkweeds are difficult to eradicate.

Greasewood (*Sarcobatus vermiculatus*)

This is a good forage plant on desert winter ranges but it is poisonous if large quantities are eaten in the spring when the leafage is succulent. Heavy losses of sheep have frequently occurred on alkali deserts of New Mexico, Utah, Nevada, and Oregon (*12, 29, 46*).

Greasewood is a shrub belonging to the goosefoot (Chenopodiaceae) family. Its scraggly, spiny branches are 3 to 8 feet high, the slender fleshy leaves ½ to 1½ inches long. It has axillary, pistillate flowers and terminal staminate spikes (Fig. 101*D*). The distribution is from Washington to Montana, southward in California to Texas.

The poisonous principle consists of oxalates of calcium and sodium. Poisoned sheep show low respiration, weak pulse, and depression. Poisoning is likely to occur only in the spring. Trailing hungry sheep at that season through dense areas of greasewood may result in extremely serious losses. Prevention consists of keeping the band away from dense areas during the spring months.

Rayless Goldenrod (*Aplopappus heterophyllus*)

The disease known as "alkali disease," "milk sickness," or "trembles" in cattle has long been known in New Mexico and Texas. In this region milk sickness has afflicted human beings through the medium of the milk or butter from diseased cows. Horses, sheep, and lambs are also affected by eating rayless goldenrod (*39*). A similar disease occurs in the central and eastern states and is caused by the animals consuming white snakeweed (*Eupatorium rugosum*).

Rayless goldenrod belongs to the sunflower (Compositae) family. It is a tufted perennial 1 to 2 feet high, with alternate leaves and numerous terminal heads in flat-topped bunches (Fig. 101*E*). The distribution is from southern Colorado to the Texas panhandle, south to Arizona and Mexico. The favorite habitats are dry plains or open woods.

The poisonous principle, tremetol, is cumulative. Cattle, horses, and sheep develop typical symptoms of the disease when they eat fairly large amounts of the plant. Calves and lambs are poisoned from the milk of diseased animals.

Livestock eat rayless goldenrod only when more palatable forage is lacking. The disease probably never occurs on ranges that are in good condition. On fenced pasture the plants may be eradicated by digging them up.

Horsebrush (*Tetradymia*)

Horsebrush (*Tetradymia glabrata*), also called spring rabbitbrush, together with gray horsebrush (*T. canescens*), are the cause of heavy sheep losses in the spring. The horsebrushes belong to the sunflower (Compositae) family. Horsebrush is a rigid shrub 1 to 4 feet high, with spreading branches which have a mat of deciduous, white, woolly hairs. The flower clusters are yellow and terminal (Fig. 101*F*). Both species are similar in general appearance. The distribution of horsebrush is from Utah westward to California and Oregon.

The toxic principle of horsebrushes is a resinlike substance of which little is known. Only sheep are poisoned. Typical symptoms are

stupor, dullness, staggering, and weakness. Death may occur in a few hours. "Bighead" or swelling of head, neck, ears, and nose is not uncommon (*15, 44, 46*).

Since the palatability of horsebrushes is low, losses occur only under stress of hunger, as along trails and on depleted range.

Prevention of poisoning consists in keeping the band away from overgrazed, horsebrush-infested range during the spring months. Hungry sheep should be placed on good feed before getting to areas where horsebrushes are abundant.

Prussic Acid Plants

In this category, three taxonomically unrelated genera are considered together, because they cause similar symptoms and because, unlike most poisonous plants, they are palatable to livestock. These genera are chokecherries, arrow-grass, and the sorghums (*11, 13, 38, 49*).

Species of chokecherry are shrubs or small trees which occur throughout the western mountains. Arrow-grass (*Triglochin maritima*) is a perennial marsh plant that resembles a grass, and that occurs from southern Canada southward to New Jersey and California. Species of sorghum are tall, exotic, annual or perennial grasses, best represented by Johnson grass (*Sorghum halepense*), and Sudan grass (*S. sudanense*). They are seeded for use as pasture or hay crops.

All of these plants produce hydrocyanic glucosides and enzymes that split the glucosides to produce hydrogen cyanide. Growth conditions greatly affect the quantity of glucoside produced and the activity of the enzyme. Consequently, cultivated varieties of sorghum, which are widely used as forage or hay, may become highly poisonous. Chokecherry, which is extensively browsed on the range, becomes dangerous at times, especially during seasons of drought or after a frost. The arrow-grass is probably influenced by growth conditions also but is dangerous at all times. Arrow-grass grows in alkaline meadows or salt marshes. Being palatable and not readily eradicated, this plant may destroy the value of pasturage and hay unless badly infested parts are taken out of use by fencing.

Hydrocyanic acid, the active principle of these plants, is a powerful respiratory poison. Its action is extremely rapid, but if a fatal amount is not taken recovery is quick and complere. An animal may eat subtoxic quantities of one of the prussic acid plants for long periods with no ill effects, but if it eats a toxic amount death may occur within an hour or less. Muscular spasms may be accompanied by champing of the jaws and by hard, audible breathing.

No treatment is practicable. The course of illness is so short rhar

Fern, bracken (*Pteridium aquilinum*)	Woods, thickets, burned forests throughout United States	Cattle, horses, sheep	Horses uncertain gait, eyes dilated, weakness, cattle difficult breathing, frothing at mouth, hemorrhages, poison cumulative
Fitweed (*Corydalis caseana*)	Stream banks, Sierra Nevada Mountains of California and Nevada	Sheep, cattle	Dullness, rapid breathing at first, later chewing of dirt and sticks, convulsions, collapse, death
Groundsel (*Senecio* spp)	Throughout United States	Cattle, horses	Nervousness, staggering gait, emaciation, weakness, and death, poison is cumulative
Halogeton (*Halogeton glomeratus*)	Deserts and dry overgrazed areas, Utah, Wyoming, Oregon, northern California and Nevada	Sheep, occasionally cattle	Rapid death, poisoning caused by presence of oxalates
Hellebore, false (*Veratrum* spp)	Wet habitats throughout North America	Horses, sheep, chickens	Salivation, defective vision, vomiting, diarrhea, prostration, death
Horsetails (*Equisetum* spp)	Wet meadows throughout United States	Sheep, horses	Loss of weight, poor control of legs, craving for the plant, low pulse, nervousness, death
Jessamine, yellow (*Gelsemium sempervirens*)	Low mountain thickets, Virginia to Florida, Texas and Central America	Cattle, horses, sheep, goats, hogs	Muscular weakness, slow breathing, decreased temperature, respiratory failure
Laurel, black (*Leucothoë davisiae*)	Moist, acid soils of northern Sierra of California	Sheep, goats	Salivation, vomiting, weakness, very poisonous
Laurels (*Kalmia* spp)	Shaded places in mountains of eastern and western United States	Sheep, goats, cattle, horses	Salivation, secretion from nose, weakness, nausea
Locust, black (*Robinia pseudoacacia*)	Extensively planted throughout United States	Cattle, horses, sheep	Colicky pains, irregular pulse, inactivity of bowels, nervous depression and collapse
Nightshade, black (*Solanum nigrum*)	Fields and waste ground throughout United States	Cattle, sheep, fowl	Loss of appetite, diarrhea, thirst, weakness, lack of coordination

little can be done to save the animals. Indeed, the first sign that poisoning has occurred frequently is the discovery of dead bodies. Animals should be excluded from areas that are badly infested by arrow-grass and from lands where chokecherry is likely to form a large part of the feed. Areas of chokecherry and sorghum should be avoided during times of drought or after frosts. Since the toxic substance is not destroyed on drying, meadow hay that may contain a considerable amount of arrow-grass should not be fed.

The Secondary Poisonous Species

In addition to the poisonous plants discussed, many other species cause livestock losses locally. These so-called secondary poisonous species are presented in Table 30, together with the more pertinent facts concerning them. Several of the more important toxic species of the eastern and southern regions are included. The genera and species discussed under the heading of primary poisonous plants are not listed in the table.

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Chapter 22

FORAGING AND PREDATORY WILDLIFE OF THE RANGE

Before the advent of domestic livestock on the ranges of North America, the population of wildlife was presumably in close balance with the forage supply. Although herbivores consume much forage, their numbers are rigidly controlled at times by carnivores, droughts, and diseases (*11*, *22*, *30*).

Big Game Mammals

Although the greatest monetary returns from wildlife are obtained from hunting, the esthetic appreciation of these animals is their greatest asset. The usefulness of a well vegetated landscape is greatly enhanced by the presence of wildlife. Knowledge of big game—their numbers, what they eat, and how they may affect other interests—is imperative to successful management of many livestock ranges and other wild lands.

Big Game Populations

Probably no continent has supported as many big game mammals as North America (Table 31).

Originally, American bison, because of their size and numbers (*47*, *48*), were the heaviest consumers of forage, deer ranking second, elk and antelope third and fourth. Most big game animals spend the summer months in mountainous regions, notably on the national forests, and the winter period in the lower country (Table 32). Fairly large numbers of big game are also found on wild lands of other ownerships, including privately owned properties (Table 33).

State and private lands, with their large numbers of white tail deer, support the largest number of cow unit equivalents and also the greatest population of big game. The national forests are second, followed by the grazing-district lands, national parks, Fish and Wildlife Service lands, and Indian lands. The total of 1,054,560 cow unit equivalents of the game, when multiplied by 12, gives the approximate equivalents

of 12,654,720 cow-months. But many plants eaten by the game animals are not grazed by livestock; also the game species may have a different digestion coefficient of the forage than domestic stock.

TABLE 31

Estimates of Original, Lowest, and 1941 Populations of Big Game Mammals in the United States (27, 28, 37, 38, 46)

Animal	*Original Populations (about 1700)*	*Lowest Level Populations and Year of Estimate*	*1941 Populations*
American bison*	60,000,000	541 — 1887	4,900
Pronghorn antelope	35,000,000	7,500 — 1920	199,000
White-tailed deer	40,000,000	1,000,000 — 1920	3,805,000
Black-tailed and mule deer	13,000,000	500,000 — 1909	2,284,000
Elk (wapiti)	10,000,000	52,000 — 1920	237,000
Desert and mountain sheep	750,000	10,000 — 1920	15,000
Mountain goat	100,000	6,000 — 1918	16,000
Moose	100,000	6,000 — 1918	12,000

* Scientific names of the animals referred to are given at the end of the chapter.

Foraging Habits

Foraging habits of the available plants are important in planning management of any big game species or in studying competition for food with domestic stock (*35*). Particularly necessary is a knowledge

TABLE 32

Numbers of Domestic Livestock and Big Game Mammals on the National Forests, 1925–1945*

Year	*Cattle and Horses*	*Sheep and Goats*	*Prong-horn Antelope*	*Deer*	*Elk*	*Moose*	*Moun-tain Goat*	*Big-horn*
1925	1,596,846	6,182,058	7,568	605,964	72,165	6,061	17,887	12,052
1930	1,338,703	6,546,460	11,142	877,780	88,214	7,764	21,866	12,496
1935	1,344,318	5,691,086	16,598	1,291,329	117,916	6,186	18,511	12,924
1940	1,176,991	4,949,196	20,000	1,813,000	154,000	7,500	19,000	9,600
1945	1,206,227	3,888,830	30,000	1,996,000	160,000	9,600	20,000	9,900

* *U. S. Dept. Agr.* "Report of the Forester," 1926–1946.

of the abundance, accessibility, and seasonal use of the forage. On the western range deer, elk, and antelope, in the order named, are probably the chief big-game competitors for forage with domestic livestock.

TABLE 33

BIG GAME IN THE UNITED STATES BY LAND OWNERSHIP (28) AND COW-UNIT EQUIVALENTS, 1941

Animal	*Fish and Wildlife Service*	*National Forests*	*National Parks*	*Indian Lands*	*Grazing Districts*	*State and Private Lands*	*Totals*	*Cow-Unit Equivalents**
White tail deer	23,473	558,886	4,515	16,698	1,270	3,200,526	3,805,368	494,697
Mule deer	8,962	1,082,500	26,063	14,933	318,411	436,860	1,887,729	324,689
Black-tail deer	135	222,000	2,830	2,017	—	169,093	396,075	68,125
Elk	11,412	160,720	24,845	1,745	5,603	32,462	236,787	125,971
Moose	52	6,823	1,415	70	90	3,390	11,840	10,289
Pronghorn	11,805	23,232	1,301	1,700	88,381	72,966	199,385	20,736
Mountain bighorn	30	7,130	950	60	1,197	801	10,168	1,800
Desert bighorn	1,009	780	1,075	233	1,775	285	5,157	912
Bighorn mountain goat	—	13,045	1,400	500	923	527	16,395	2,361
Bison	1,315	—	1,285	909	221	1,250	4,980	4,980
Cow equivalents, totals	13,458	394,155	21,985	7,285	68,063	549,614	—	1,054,560

* Conversion equivalents taken from Rasmussen and associates (39).

Forage Preferences of Deer The food of deer as with most other foraging animals, varies with season and locality They prefer fully as many species of forbs as sheep and the foliage, twigs, and fruits of as many species of trees and shrubs as sheep and goats combined

In California (*17*, *18*, *41*, *42*) during winter and early spring deer consume species of filaree (*Erodium*), clover (*Trifolium*), dock (*Rumex*), knotweed (*Polygonum*), thistle (*Cirsium*), mule s ears (*Wyethia*) bracken fern (*Pteridium*), and many other forbs In early spring they eat large amounts of grasses and grasslike plants soft chess (*Bromus mollis*), ripgut (*Bromus rigidus*), bluegrass (*Poa* spp), fescue (*Festuca* spp), wheatgrass (*Agropyron* spp), and sedges (*Carex* spp) Leafage of mature, dry grass or sedge is not taken, but the seed heads of some species are eaten Browse is cropped at all seasons Several species of *Ceanothus* are utilized extensively, most widely sought are deerbrush (*C integerrimus*) during the growing season and wedgeleaf ceanothus (*C cuneatus*) at all seasons Bitterbrush (*Purshia tridentata*) and mountain misery (*Chamaebatia foliolosa*) provide choice winter browse Other useful browse plants are currant (*Ribes* spp) dogwood (*Cornus* spp), juniper (*Juniperus* spp), mountain mahogany (*Cercocarpus* spp), oak (*Quercus* spp), redbud (*Cercis occidentalis*), serviceberry (*Amelanchier* spp), thimbleberry (*Rubus* spp) willow (*Salix* spp), wild cherry (*Prunus* spp) and, on burns, young crown sprouts of such plants as chamise (*Adenostoma fasciculatum*) (*40*) manzanita (*Arctostaphylos* spp), and other woody species (*41*)

In the Southwest, aspen (*Populus tremuloides*), cliff rose (*Cowania stansburiana*), juniper, and mountain mahogany are favored browse plants Most species of oak acacia, and mesquite (*Prosopis* spp) are utilized seasonally

Forage Preferences of Elk No other big game animal has as diversified food habits as elk Where available, grasses sedges, and rushes provide the greater part of their food yearlong (*43*) When snow covers the low growing vegetation elk will exist for long periods on browse Western aspen, birch (*Betula* spp), and willow are especially sought (*48*) Their great reach permits elk to subsist where competing deer might starve

Since elk feed extensively on grass, they sometimes compete sharply with cattle and horses for forage Elk calves begin to eat grass when they are 3 weeks old A mature elk cow weighs about 500 pounds, a bull about 800, and they consume from one half to three-fourths as much forage as a mature domestic cow

a selected clientele In many instances investment in cabins, horses, and other needed equipment returns a bigger profit than livestock grazing—an incentive to favor both game and livestock

The winter foraging requirements of big game are by far the most difficult to provide (*34*) Too often spring-fall ranges, which have been grazed to capacity by cattle or sheep during the growing season, are overutilized by deer or elk in winter This has resulted in starvation of the game, destruction of forage, and accelerated soil erosion

The remedy lies chiefly in (1) reducing the game to reasonable numbers by hunting and in other ways, (2) making available sufficient winter foraging grounds for the game Adjustments of this nature require that sportsmen sanction proper control of the game population, also that stockmen reduce their own herds or bands before irreparable range damage has been inflicted (*12, 51, 53*)

A balanced production of livestock and game can best be carried out on Federal lands where conflicting viewpoints may be settled by study of the problem through intelligent representatives of all interests

Effects of Rodents and Rabbits on Range Resource

On fully utilized and particularly on weedy ranges, game and livestock frequently must compete for forage with various small animals, particularly rodents and rabbits

The damage caused to the range by these small animals has been estimated at 150 million dollars annually, and a like amount of damage has been done to cultivated crops (*36*) But not all rodents are harmful, neither is a species that is harmful in one region necessarily so in others Some rodent species are beneficial as soil builders, others feed largely on insects which otherwise would harm crops, still others have great economic value as fur bearers

Among the beneficial rodents should be mentioned the banner-tailed kangaroo rat, which, in Arizona, was found to contribute nitrates and other nutrients to the soil equivalent to 30 cents per acre if applied as commercial fertilizer (*8*) Kangaroo rats, pocket gophers, and such nonrodents as the mole aerate and hasten soil formation (*24*), but where overly abundant they destroy much forage Taylor (*56*) concluded that on properly managed ranges rodents evidently do not promote soil erosion According to Horn and Fitch (*26*), working in California "The forage consumed and destroyed by pocket gophers is largely compensated for by the increase of forage brought about by their cultivation of the soil" Usually abundance of population determines whether a control campaign is justified As a rule increased numbers of several species of rodents are the result of a depleted range These

animals, especially squirrels, jack rabbits kangaroo rats, and woodrats (*55, 58*), subsist primarily on the secondary succession weedy plants But cottontail rabbits and pocket gophers often increase in numbers as the forage becomes more dense

The most widely destructive species on the ranges are prairie dogs, ground squirrels, and jack rabbits, of lesser importance are pocket gophers, kangaroo rats, and mice

Prairie Dogs

These rodents resemble ground squirrels but are larger and stouter bodied (Fig 102*A*) They live in burrows, the entrances to which are crater-shaped mounds up to 10 feet in width Prairie dogs are often numerous on range lands in interior North America, with Colorado about the center of distribution None are found in the Pacific Coast states (*44*)

Prairie dogs subsist mostly on the forage grasses that are most sought by cattle and horses On experimental plots in Arizona, Zuni prairie dogs destroyed 80 percent of the blue grama, 69 percent of the western wheatgrass, most of the sand dropseed and 80 percent of the total potential annual forage (*57*) Often they destroy the palatable grasses so completely that they must move to new areas for food In drought years competition between prairie dogs and livestock becomes deadly Control campaigns must, therefore, be active and continuous

Ground Squirrels

These burrow-digging animals (Fig 102*B*) consume much choice forage (*17, 20, 22*) In California, filaree, bromes, and fescue grasses are staple diet Ground squirrels take the heaviest toll of forage in the spring when the population is fully active and the young squirrels are out (*16, 26*) Some 200 ground squirrels on the open California range may eat as much green forage as 1 cow, 20 as much as 1 sheep (*16*) In Washington, 385 Columbian ground squirrels ate as much forage as 1 cow, and 96 as much as 1 sheep (*49*) Populations ranging from 15 to 75 ground squirrels per acre are not unusual Reproduction is so rapid that a control campaign must destroy 85 percent of the population in 1 year to appreciably reduce numbers the next.

Pocket Gophers

These small, tunnel-digging rodents (Fig 102C) store a great variety of food acorns, roots, and bulbs. In spring and summer, gophers consume filarees, clovers various grasses, and weeds, in winter they feed on underground plant growth The loss of forage is formidable where

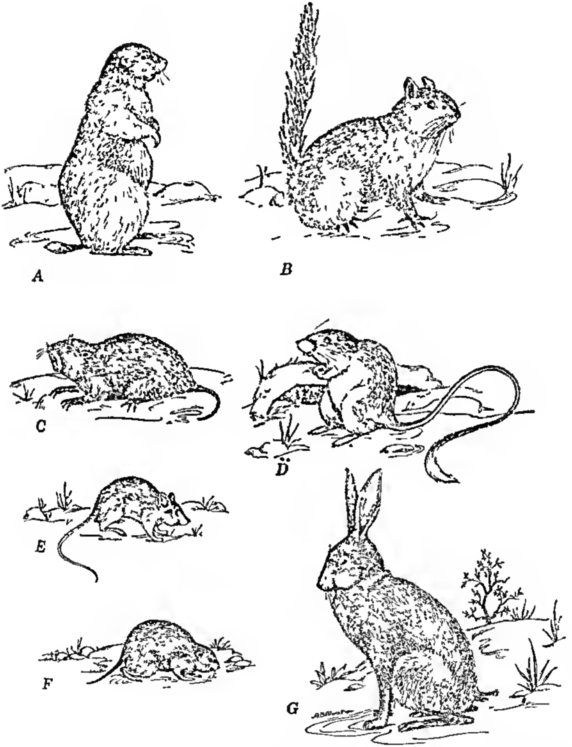

FIG. 102. Examples of common range rodents and jack rabbit, all of which consume much forage where conditions favor their abundance. *A*, Zuni prairie dog, *B*, Beechey ground squirrel, *C*, western pocket gopher, *D*, kangaroo rat, *E*, white-footed mouse, *F*, meadow mouse, *G*, Arizona jack rabbit.

the population is heavy. But the loosening up of the soil by their tunneling is recognized as beneficial (13, 15) (Chapter 23).

Kangaroo Rats

The numbers of these small, long hind-legged and long-tailed rats (Fig. 107D) can best be estimated by their conspicuous burrows. The rats are most abundant in open places where vegetation is sparse. Their food consists mainly of seeds and tender growth of grasses and forbs, green cured foliage, pine nuts, and knick-knacks (26, 60). Much of this material is stored in their dens for use in winter. Their effect on the range is greatly influenced by wide fluctuations of their numbers from year to year.

Meadow and Other Mice

Meadow mice (Fig. 107F), harvest mice, white-footed mice (Fig. 107F) and some others often termed "field mice" damage the range by cutting green grasses and forbs, ruining hay in loose cocks or stacks, and devouring bulbous plants. In years when their populations are high, loss of forage is conspicuous (45, 52).

Jack Rabbits

Over extensive range areas of low to medium elevations jack rabbits (Fig. 107G) compete tellingly with livestock for forage (61). In the Southwest, 15 antelope jack rabbits ate as much range forage as 1 sheep and 74 as much as 1 cow (52). 30 black-tailed jack rabbits consumed as much as 1 sheep and 148 as much as 1 cow. About one-fourth to one-half of their food consisted of grass. Since the population of these jack rabbits was estimated at 95 per section (640 acres), they consumed enough forage to maintain 6 sheep or 1 cow. Haskell and Reynolds (25) found that an adult California jack rabbit consumed 0.27 pound of air-dry native forage per day.

Excessive livestock grazing is primarily responsible for initial deterioration of the forage and increase in rabbit numbers (1). On overgrazed range, destruction of the jack rabbits seems necessary. But control must be accompanied by adjustment in livestock numbers if real benefit to the range is to be achieved.

Control Measures

Control of rodent and rabbit numbers is not simple, for each species in each ecological niche presents an individual problem. Jack rabbits, prairie dogs, and ground squirrels should normally be held in check

other destructive rodents should be controlled only where the population is exceptionally high

Rodent populations can be checked through *natural* control by predators, food supply, and disease, and through *artificial* control by man

Natural Control Such animals as the coyote, bobcat, fox, weasel, badger, striped skunk, ferret, hawk, owl, rattlesnake, and gopher snake depend largely on rodents and rabbits for food Therefore, a strong, virile population of rodent eaters, except for the coyote and the bobcat which prey on livestock, should be maintained Certain diseases are also known to cause a sudden downswing in the rodent population

Artificial Control Man's control consists of poisoning, trapping, shooting, and sometimes fencing Best control requires knowledge of life histories and food preferences of the different rodent species (*20, 21*)

Poison bait is used most extensively Food relished by rodents—grains, cured green leafage, pieces of fruit or vegetables—is poisoned and placed in burrows or runways or scattered broadcast where live stock or other animals will not be harmed The principal poisons used are strychnine for prairie dogs ground squirrels, jack rabbits, and pocket gophers, and red squill, barium sulfate, and zinc phosphate for meadow and field mice

While phosphorus, thallium sulfate, and '1080' (sodium fluoroacetate) have been tried on ground squirrels and rats and arsenic and barium on rats (*33, 52*), they are too dangerous to men and other animals for general use Thallium is being controlled by legislation in some states, including California The substance '1080' is toxic to all animals and may kill cats and dogs that devour poisoned rodents There are no antidotes for either of these poisons

Commercial rodent control preparations are sold under various trade names Those not wishing to prepare the poison mixture recommended by their agricultural state college should consult the county agent or the agricultural commissioner of the community as to the most suitable poison

Fumigants are mostly employed to destroy the rodents remaining after a vigorous poisoning campaign Carbon disulfide, the most popular fumigant, is used effectively against burrow inhabiting rodents Carbon monoxide gas from the exhaust of automobiles and tractors is also effective The so called 'virus' of certain bacterial cultures often fails to reduce the rodent populations and may be dangerous to other animals

Tabulation of Control Measures of Small Mammals

Various useful facts concerning control of the small mammals are presented in Table 34 (*3*, *30*, *50*).

Effects of Invertebrates on Range Resource

Periodically, grasshoppers, bark borers, caterpillars and other insects become numerous enough to destroy much of the season's herbage (*4*, *11*, *59*).

Overgrazing favors the prevalence of some species of harmful grasshoppers, therefore, an effective revegetation program should be carried out. Artificial control of grasshoppers and other such pests may be expected through use of arsenic mixed with bran and sawdust as bait.

Mammals That Prey Upon Livestock

Losses of livestock from predatory animals run into millions of dollars annually. Fortunately, various agencies are assisting stockmen in curbing the activities of these enemies.

The most destructive livestock and big game predators in North America—approximately in order of damage inflicted—are coyote, mountain lion, wildcat and lynx, wolf, black or brown bear, and grizzly bear. These animals occur most abundantly from the Great Plains region westward to the coast and inhabit the region once heavily populated by elk, deer, buffalo, antelope, and mountain sheep. As the game animals retreated to the back country or became scarce, predators shifted to domestic livestock.

Coyote

These cunning range "diplomats" are yellowish gray, with strong, coarse hair, especially on ears, neck, throat, shoulders, and breeches, and bushy tail (Fig. 103). They are lean, wiry, and fleet-footed, weighing about 25 pounds, and their syncopated howling and graceful movements furnish much local color (*14*, *37*).

Rabbits rank first in food supply of coyotes, rodents, particularly field mice and pocket gophers, rank second. Although coyotes kill some calves they are much more destructive to sheep and goats.

Control is accomplished by den hunting (*65*), shooting, and trapping. Fencing sheep range lands coyote proof was found to be expensive but it minimized losses (*29*), made for better gains of the band, and improved the forage stand.

TABLE 34

FACTS CONCERNING REPRODUCTION, NATURAL ENEMIES AND CONTROL BY MAN OF RABBITS AND RODENTS

Name	*Chief Food*	*Gestation Period, Number of Young per Litter*	*Control by Natural Enemies*	*Control by Man*	*Kind, Method, and Season for Poisoning*
Jack rabbit	Grass, other herbs, and shrubby growth	About 30 days, 2–8	Coyote, fox bobcat, hawk, gopher snake	Poisoning, when population is high, shooting, exclusion by fencing	Strychnine sulfate (HS_2) on alfalfa leaves or oats in winter
Ground squirrel	In spring, grass and green herbage, in fall, seeds	28 days, 2–15	Hawk, owl, red fox, coyote, bobcat, weasel, gopher snake, rattlesnake	Poisoning, followed by fumigation	Strychnine on barley baiting trails in spring, carbon disulfide in burrows
Prairie dog	Green and cured grass, seeds, roots	28–32 days, 2–10	Owls, prairie falcon, weasel, skunk, coyote, badger, ferret, rattlesnake	Poisoning, followed by fumigation	Strychnine on oats or dandelion greens in winter and early spring
Pocket gopher	Roots, tubers, bulbs, top growth of grasses, frequently shows little choice	About 40 days, 1–6	Owl, coyote, wildcat, weasel, ferret, owl, gopher snake, rattlesnake	Poisoning and trapping	Strychnine alkaloid or sulfate on sweet potato or parsnips, bait runways when field conditions are favorable
Kangaroo rat	Seeds of grasses and other herbs, green vegetation	About 30 days, 2–5	Same as for pocket gopher	Poisoning	Strychnine or barium carbonate on barley placed near burrows, preferably during dry season
Meadow mouse	In summer, green vegetation, in winter, woody and herbaceous plants	21 days, 2 8	Same as for pocket gopher	Poisoning	Strychnine, red squill or barium carbonate on barley grain set in runways or broadcast, when population is at maximum
Harvest mouse	Seeds and tops of succulent vegetation	23–24 days, 1–7	Same as for pocket gopher	Poisoning	Same as for meadow mouse

Mountain Lion

These big cats—also called cougar, puma or panther—have a flexible, lengthy spine, small head, loose skin, and are supple and strong They measure 7 to 9 feet from head to end of the long round tail and weigh 100 to 275 pounds (67) The distribution is wide in North and South

Fig. 103 The coyote—the sheepman's arch enemy.

America, corresponding to that of deer, elk, antelope, and various smaller mammals upon which they largely subsist (37) They kill young cattle, horses (especially colts), pigs, sheep, and goats Shooting and hunting with hounds, stimulated by attractive bounties, tend to hold down their numbers

Bobcat and Lynx

These "wildcats" are among the most widely distributed and best known of our predators The bobcat (Fig 104) weighs about 20 pounds and is distinguished from the widely distributed Canada lynx by

its lighter weight, a more slender body, less conspicuously tufted ears, and the tail which is black only on the upper half Bobcats range from Nova Scotia and southern British Columbia over most of the brushy and woody area of the United States The Canada lynx is confined in the United States to the cool areas of the eastern states and the

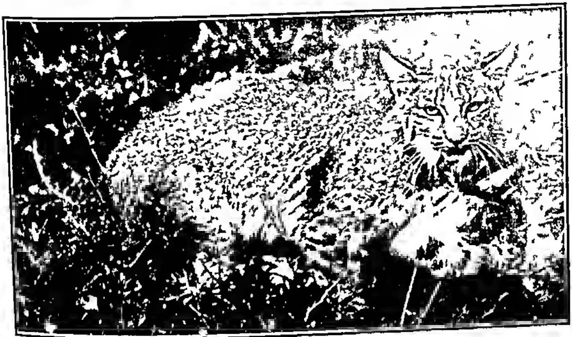

FIG 104 Bobtailed cat, or wildcat, a frequent lamb killer

Rocky Mountain and Sierra Nevada ranges of the West Although they feed extensively on rabbits, rodents, and birds, these cats often feast on domestic fowl and lambs (*37, 46*) They are fairly easily trapped (*64*) and readily "treed" when hunted with dogs, yet their population remains high

Gray or Timber Wolf

This progenitor of the domestic dog is the most widely distributed of the large wolves in North America It is gray, weighs 60 to 175 pounds, and differs from the coyote in having less pointed features, more rounded ears, heavier muzzle, and proportionately shorter tail (*66*) Though formerly abundant over a large region, it now occurs sparingly in parts of the cooler stretches of the Gulf States and Mexico to northern Michigan, and westward throughout the Rocky Mountains (*5, 63, 66*). It is still abundant in parts of Alaska and Canada The food habits of the gray wolf are much the same as those of the coyote, except that it more frequently kills calves, full-grown cattle, goats, and hogs, often causing appalling losses

Bear

Bears cannot be classed as full-fledged predators (*37, 46*), but an occasional bear kills lambs and stampedes the band on the bedground, sometimes causing heavy sheep losses from piling and suffocation.

Black (brown) bear are the most numerous; they weigh up to 400 pounds. Since they can readily climb trees they are easy to hunt with dogs. The much more ferocious grizzly bear, which weighs up to 1000 pounds, is now confined to the timbered back country and cannot climb trees. The food of bears consists of plant materials and of animals that have mostly died naturally.

Dogs

On farms in the South and East—less commonly in the West—sheep-killing dogs, of a "Jekyll-Hyde" existence, make sheep raising hazardous. Various laws have been passed to curb the dog menace, but none has been effective. Raising sheep in dog-proof pastures is the best protection (*62*).

Facts Pertinent to Control of Predators

A summation, including life histories of predatory animals, is presented in Table 35.

Measuring Wildlife Populations

Censusing of animal populations is often needed to determine the relation of wildlife to the forage supplies and other land uses. The execution of a census frequently requires a specialized technique based upon knowledge of habits and habitat of the species concerned (*30, 32*).

A census measures either actual or relative numbers of animals. Actual numbers are most often determined by direct tally of the animals. A relative census counts such indicators as pellets, tracks, or dens.

Complete censusing of animals in an entire range area is expensive and seldom done. More often counts are made on a representative range unit.

Some of the more popular techniques employed to census big game, small mammals, and bird life are discussed below.

Censusing Big Game Mammals

Big game can be censused most satisfactorily by direct enumeration from an airplane or by a drive on foot.

TABLE 35

FACTS CONCERNING DISTRIBUTION, REPRODUCTION, FOOD HABITS, AND CHIEF CONTROL MEASURES OF LIVESTOCK PREDATORS

Animal	*Distribution and Habitat*	*Breeding Habits*	*Chief Foods*	*Control Measures*
Coyote	Mississippi to Pacific Coast, Costa Rica to Athabasca, prairies, desert, washes, brush and timberlands	Breeding season, midwinter, gestation period about 60–65 days, 5–7, up to 14 per litter, monogamous	Large game, lambs, calves, rodents, rabbits, fish, reptiles, some fruits and berries	Strychnine 1½ grains in pellets and carcasses, No 3 or 4 double spring trap, hunting, cyanide gun,* digging out dens, bounties
Wolf	Originally throughout North America, foothills, plains, badlands, and wooded mountains, now extinct or nearly so in many regions	Breeding season, midwinter, gestation period about 63 days, 4–9 per litter, monogamous	Bison, deer, elk, antelope, rodents, cattle, sheep	Same as for coyote, but 2 grains of strychnine and No 4½ double spring steel trap Bounties frequently offered
Mountain lion	Big game areas of North and South America, and woodland, crags, and badlands	Breeding season, winter and spring, 2–5 per litter, gestation period 96 days	Deer, elk, mountain sheep, small mammals, horse and mule colts, young cattle, pigs, sheep, and goats	Hunting with rifle and hounds, poisoning and trapping with No 4 trap and drag
Bobcat and lynx	Throughout North America, wooded and brushy mountains and lowlands	Breeding season, late winter and spring, 2–4 per litter, gestation period about 68 days	Rodents, rabbits, birds, chickens, quail, grouse, young mountain sheep, deer, antelope, lambs	Trapping with No 2 or 3 double spring steel trap, hunting and shooting, using trail dogs
Black (brown) bear and grizzly bear	Black bear throughout wooded areas of North America, grizzly in western North America — now extinct in California and some other states	Breeding season, late fall and winter, gestation period 6–7½ months, 1–4 (usually 2) per litter, hibernate in cold weather	Berries, bulbs, leaves, honey, eggs, insects, carrion, occasionally sheep, calves, pigs	Hunting and trapping, black bear rather easily treed by dogs, grizzly bears cannot climb trees

* The cyanide gun or "coyote getter," is a small device shooting a 38 caliber pistol cartridge loaded with a cyanide salt—calcium or sodium cyanide The "gun" is buried in the ground, with a small piece of rabbit or squirrel skin projecting above the ground as a bait or attractant When the coyote grasps this bait in its mouth the gun is discharged, throwing the cyanide directly into the animal's mouth Use of this device is strictly limited, because dogs and fur bearers are just as vulnerable as coyotes

Counts from an airplane are relatively cheap and effective where the vegetation is open. Pronghorn antelope, bighorn sheep, mountain goats, and bison can be counted from a plane at any season under most conditions. The method is also adaptable to deer, elk, and caribou in the winter when the animals band together (*6*).

In brushy or rough country which precludes the use of a plane, the game "drive," although expensive, is more satisfactory. Individual drive units are usually from 200 to 500 acres in size. The sample areas should be representative of the plant cover and include about 10 percent of the total surface area. Watchers are stationed on the downwind sides of a well-defined triangle, and drivers force the animals to pass between observation points. Each watcher tallies and notes the condition, sex, and other characteristics of the animals crossing the boundary.

Local populations of certain species of big game have sometimes been estimated by the use of mathematical ratios (*32*). This has been done by first tagging cage-trapped animals and releasing them in the herd and then comparing their ratio of frequency either by visual count in the herd or by kill records.

Index methods have also proved useful in counting certain big game species. On snowy ground, caribou, deer, and moose tracks can be counted along migration routes. Counting of tracks around waterholes has been used in determining the number of desert bighorn (*19*).

Pellet group counts are used occasionally for deer (7). If defecation rates are known, actual numbers of animals can be determined.

CENSUSING SMALL MAMMALS

Small mammals may be censused by observation, trapping, and various index methods. Probably the most accurate method is that of trapping to exhaustion by live or by breakback traps on sample plots (*10*).

The number of animals caught per "trap-night" on a trap line has sometimes been used as an index of abundance. A refinement of this method is that of noting the numbers of individuals of each sex and age caught per unit length of trap line. All trapping methods are affected by the kind of bait and traps used, and by the season of the year, forage, and animal habits.

Popular index methods for some animals are the pellet and bait counts. The number of pellets per unit area indicates rabbit populations (*2*). Disturbance of mechanically spaced bait piles (*23*) or number of dead animals along poison-bait lines (*55*) helps determine relative abundance of animals. Disadvantages of the poison-bait

method are the difficulties of finding all poisoned animals and the danger of killing species other than those being censused. However, the index methods mentioned above involve minimum labor.

Censusing Bird Life

Ground-feeding birds are occasionally an important factor in the success of range reseeding, for seeds provide an important part of their diet.

Some species, like quail and doves, can be counted by noting "singing" males during the mating season on sample areas. Counts are then doubled and applied to the entire area for computing total populations.

Grouse and sage hens can be enumerated by flushing along a sample strip, with or without the use of a dog. Grouse and woodcocks are often counted on singing grounds during the mating season.

Waterfowl are sometimes censused by photographing from an airplane when the birds are on nesting, resting, or feeding grounds (*6*). Some birds may be banded and the total populations determined from kill returns, as was explained for deer by an index method (*31*). Migratory birds such as waterfowl, doves, and pigeons can be censused by noting passing flocks.

Choice of Census Method

Which method is used depends on species of animals, season of year, and kind of vegetation composing the habitat. The census method used should furnish as much information about the animal as possible in keeping with the objective and cost of the survey. More elaborate and sensitive methods can be used for research than for administrative purposes.

Wildlife and Range-Management Relations, A Summary

The most pressing wildlife problems, in general, concern the big game mammals. Despite conspicuous habitat changes these animals appear at this time to be fairly secure from extermination (*28*). Although sportsmen welcome these population increases in the West, wildlife managers and stockmen often are concerned about them because of the added grazing pressure and competition for forage between range stock and game. Excessive cropping by livestock and big game also is often accentuated by increased numbers of rodents.

Stoddart and Rasmussen (*51*) point out that in the arid western states the vegetation is delicately balanced and cannot endure heavy grazing.

The best forage plants are sometimes killed, leaving less valuable plants which are little grazed. These are green and appear to the uninformed

to be good feed The armchair sportsman examining such a range is inclined to argue that there is plenty of feed although deer and livestock actually may be starving Stockmen who live on the range have not all learned to recognize good and bad plants, and they, too, often are misled in judging range conditions

Since the western winter ranges for deer and elk are the spring-fall feeding grounds for domestic stock, their grazing capacity—much more than the summer range—must determine game numbers for the entire range To abuse these areas by overgrazing obviously precludes the possibility of sustained yields of game

Among big game, malnutrition resulting from overpopulation causes far heavier losses than predators Control of predators is not justified where the annual crop of game animals is not fully utilized or where overpopulations occur

Where the range has become depleted because of a combination use of domestic stock and big game, the numbers of one or both of these animals should be reduced until proper forage utilization is attained Where the big game animals must be measurably reduced, shooting of both sexes should be permitted until the herd is decreased to the point needed Certainly the maintenance of an adequate habitat for the game ranks first in management planning, and this requires proper stocking (50)

An excessive population of big game often induces the animals to seek food on bordering agricultural lands, such as alfalfa fields and orchards. In these cases the state game commission and the local sportsmen must recognize the duty of correcting the situation and give the stockman the protection that he has a right to expect. Ordinarily, the first thing to do is to permit shooting the habitually guilty animals Control of deer and elk by fencing, herding, or the use of scare bombs is seldom effective, and payment for the damage is rarely practical or satisfactory

The fact should at no time be overlooked that where an adequate habitat for big game is maintained few complicated managerial problems arise Habitat decline brought about by the combined grazing of livestock and game may require adjustment in numbers of both these classes of animals Occasionally the domestic stock must be removed permanently, but such a measure may accomplish little unless the game numbers are also reduced in accordance with the recovery requirements of the range

If wildlife management is to succeed, man must be better informed on the ecology and life history of the species concerned He must know especially about food and cover requirements, preferred habitats

and their grazing capacity, migration routes and circles, breeding habits, population cycles, diseases, predators, and man-made controls. More information is needed as to the effect of livestock grazing and plant succession on the food supply of rodents, the effectiveness of control measures, and the extent to which these animals may move in from uncontrolled lands.

Improved wildlife management calls for additional research of strong leadership by administrative officers. It is especially important that the public be kept informed of the problems and of their proposed solution. Not until sportsmen and stockmen are more conversant with what constitutes adequate habitat and desirable range condition can the desired cooperation among these groups be expected.

Future Guidance in Solution of Wildlife Management

Various acts and organizations have been established in recent years, which are shaping national policies in wildlife management and stimulating interest and progress in recreational fields. According to Swift (54), the following events have been particularly influential in making these aims possible:

1. *Enactment of the Taylor Grazing Act in 1934* placed large areas of public lands under Federal administration and provided representation of wildlife interests on each advisory board.
2. *Establishment of the Soil Conservation Service in 1935*; it includes biologists who are studying wildlife food and cover requirements.
3. *Organization of cooperative wildlife research units*, initiated in 1935, involving 10 colleges and universities, has resulted in training of several hundred wildlife managers.
4. *State fish and game commissions with plenary powers* have greatly facilitated sound fish and game seasons and other regulations.
5. *The North American wildlife conferences*, initiated in 1936, have stimulated useful interchange of ideas on wildlife matters among the numerous administrators and technicians.
6. *Establishment of a Division of Wildlife Management in the Washington headquarters of the U. S. Forest Service in 1936* resulted in appointment of wildlife technicians in all national forest regions.
7. *Passage of the Pittman-Robertson Act of 1937*, designed to provide aid to the states for restoration of wildlife, has greatly stimulated game management action programs in the states under the leadership of professional wildlife men.
8. *Formulation of the Wildlife Society in 1937* has resulted in professional solidarity and maintenance of professional standards. The *Jour-*

nal of Wildlife Management of this Society is a valuable tool for game technicians.

9 *Consolidation of Biological Survey and Bureau of Fisheries in 1940* strengthened the influence of Federal wildlife by enlargement of the refuge system by closer contact with the states through the Pittman-Robertson Act, and through improved efficiency of migratory bird laws

The relationships mentioned should become increasingly effective in promoting better cooperation and understanding of wildlife problems as a whole and in training and employment of qualified young men in this important field

List of Animal Names

American buffalo (*Bison bison*)
Antelope ground squirrel (*Citellus leucurus*)
Antelope jack rabbit (*Lepus alleni alleni*)
Arizona jack rabbit (*Lepus californicus eremicus*)
Banner tailed kangaroo rat (*Dipodomys spectabilis spectabilis*)
Beechey ground squirrel (*Citellus beecheyi beecheyi*)
Bighorn sheep (*Ovis canadensis*)
Black (brown) bear (*Ursus americanus*)
Black tailed deer (*Odocoileus hemionus*)
Black tailed jack rabbit (*Lepus californicus*)
Bobcat (*Lynx rufus*)
Broad footed mole (*Scapanus townsendi*)
Canada lynx (*Lynx canadensis*)
Columbian ground squirrel (*Citellus columbianus columbianus*)
Cottontail rabbit (*Sylvilagus* spp)
Coyote (*Canis latrans*)
Deer (*Odocoileus* spp)
Domestic dog (*Canis familiaris*)
Douglas ground squirrel (*Citellus beecheyi douglasii*)
Elk or wapiti (*Cervus canadensis*)
Ferret (*Putorius furo*)
Gopher snake (*Pituophis catenifer*)
Grizzly bear (*Ursus horribilis*)
Harvest mouse (*Reithrodontomys* spp)
Jack rabbit (*Lepus* spp)
Kangaroo rat (*Dipodomys* spp)
Marmot (*Marmota* spp.)
Meadow mice (*Microtus* spp.)
Moose (*Alces americana*)
Mountain goat (*Oreamnos americanus*)
Mountain lion (*Felis concolor*)

Mountain sheep (*Ovis canadensis*)
Mule deer (*Odocoileus hemionus*)
Pocket gopher (*Thomomys* spp)
Prairie dog (*Cynomys* spp)
Pronghorn antelope (*Antilocapra americana*)
Rattlesnake (*Crotalus* spp)
Red fox (*Vulpes* spp)
Skunk (*Mephitis* spp)
Weasel (*Mustela* spp)
White-footed mouse (*Peromyscus* spp)
White-tailed deer (*Odocoileus virginianus*)
Wolf (*Canis nubilis*)
Woodrat (*Neotoma* spp)
Zuni prairie dog (*Cynomys gunnisoni zuniensis*)

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SOIL EROSION AND ITS CONTROL

Through the ages, rain, running water, waves, moving ice, and wind have been at work making great valleys, plains, drainage channels, and deltas Even so, during the epoch of primitive man, the topsoil over much of the earth's surface was formed faster than the forces of erosion carried it away

But during the relatively short span of time that civilized man has exploited the earth—his livestock thinning the pasture vegetation and his plow breaking the sod—soil has been removed at a much faster rate than it was built up

On parts of all continents erosion has exacted a heavy economic toll Man-made deserts, and ruined cities amid barren wastes, attest to the devastating power of uncontrolled erosion (*30*) The 728 million acres of grazing land in the western states do not provide forage for half the animal units that they did 50 years ago (*8*) At least 589 million acres, or 80 percent of the western range, have eroded in varying degrees of seriousness (*2*, *3*, *6*, 7) But the toll is not confined to the West On the Atlantic Coast, in the Coastal Plains regions, the Northeast and Midwest, soil erosion is the most critical single factor in pasture- and row-crop production Indeed, erosion accounts largely for lowered living standards, the abandonment of extensive rural lands, many land-tax delinquencies, and the diversion of vast acreages to county and state governments

Erosion not only entails a loss to the area whence the soil is removed, but also to the land on which it is deposited—for example, by impeding navigation of inland waters and lowering water supplies

Correction of this evil on range lands lies primarily in the reestablishment of the vegetation and in improved land and livestock management

Geologic *vs* Accelerated Erosion

This chapter deals with accelerated and not with geological erosion

Geologic or "Normal" Erosion

Under conditions of geologically normal rates of erosion a near equilibrium exists among the soil, the vegetation, and the climate The

two major forces of erosion—water and wind—are largely nullified by a dense plant cover, which is maintained by further accumulation and conservation of the topsoil (35) Geologic erosion, then, implies that the soil is removed more slowly, or at least not faster, than it is formed

Soil genesis is slow (27), the rate varying according to climate organisms present, relief, vegetation, kind of parent material, and extent of fragmentation or pulverization of the rock Chamberlin (11) speculates

> We have as yet no accurate measure of the rate of soil production We merely know that it is *very slow* I should be unwilling to name a mean rate of soil formation greater than one foot in 10,000 years on the basis of observation since the glacial period I suspect that if we could positively determine the time taken in the formation of the 4 feet of soil next to the rock over our average domain where such depths obtain it would be found above rather than below 40 000 years

Accelerated or 'Destructive' Erosion

Abnormally rapid removal of soil—'man induced' erosion—occurs where the environment has been altered, as by faulty grazing or tillage Effective control measures must be applied right from the start

Common signs of initial accelerated erosion are (1) turbidity of streams and washes during periods of heavy rainfall, (2) accumulation of sticks and rocks against surface obstructions, (3) deposition of soil at the base of a slope where the velocity of the water flow is broken, (4) formation of small rills over the soil surface, (5) movement of fine soil particles during periods of strong winds

Common signs of advanced erosion are (1) intensification of the previously mentioned indicators—soil accumulations, severe gullying, and stream turbidity, (2) thinning of vegetation and a downward trend in the succession of the plant cover, (3) exposure of subsoil or parent material, (4) presence of an 'erosion pavement,' that is, accumulation of stony material on the surface, (5) vegetation growing on hummocks, owing to removal of soil from between the clumps or deposition of soil in the hummocks, (6) a shortened period of flow of springs and streams, (7) greater fluctuations in flow of streams, with abnormally high flow immediately after a storm, and flooding of the lowlands

Patterns of Soil Erosion

There are seven distinct patterns of erosion (1) sheet erosion, (2) gully erosion, (3) stream erosion, (4) landslide or slip erosion,

(5) creep erosion, (6) wave action erosion, and (7) dune and dust-storm erosion. Which of these patterns dominates in an area depends on topography, soil type, vegetation, land use, and climate.

Sheet Erosion

This occurs when a thin layer of the finer surface soil particles is removed more or less uniformly from a land area. The runoff waters carry the finer soil particles down the exposed slope. Although sheet

FIG. 105. Results of a combination of sheet and gully erosion near timberline resulting from destruction of the cover by excessive grazing. Wasatch Mts, Utah. [*From* Range and Pasture Management, *by the author* (*40*).]

erosion is inconspicuous in the earlier stages, it is the most destructive form of soil removal (Fig. 105). Wind carries off the remaining loosened soil particles when the surface has dried. On denuded areas mere raindrop splash may result in transporting large amounts of soil downhill without overland flow. Soils of light surface texture and those having high silt content are especially subject to damage by sheet erosion (*33*).

Gully Erosion

This is the process whereby silt-laden runoff cuts channels in the soil. Many gullies typically occur near the slope's summit; farther down the gullies unite fanlike to form more prominent channels. In

the early stages the gullies are V-shaped, later, as the soil on the banks sloughs off, they become U-shaped. Gully erosion is favored by increase in slope, reduction in density of the vegetation, and rolling topography, and it is frequent in regions where rain storms are sharp.

Stream Erosion

This all too common type of erosion occurs when a large volume of water cuts into river banks. During each high water period materials previously deposited in the stream bed are carried to a newly formed island of conglomerate, or into storage reservoirs or transmission facilities, or are deposited in the sea.

Landslide or "Slip" Erosion

Sometimes called "land slump," this involves sudden mass slippage of soil and rock, usually near the end of a protracted rain storm. It

Fig. 106. Landslide or "slip" erosion on a moderate slope. This site was originally clothed with timber and brush. Frequent burning and overgrazing of the succeeding shallow rooted grass and forb cover appear to favor land slips. Mendocino County, Calif.

appears to be most common where deep-rooted vegetation has been destroyed. The break-off usually occurs a short distance below the hill's crest, where the deep, usually heavy textured soils slide in a body (Fig. 106). Soon gullies are formed, which carry soil and rock to lower levels.

Creep Erosion

This form of erosion occurs commonly on steep slopes during the dry period. Being more or less continuous day and night, it accounts for much soil movement. Such sloughing of soil and gravel is most conspicuous on lightly vegetated steep slopes, the animals literally pushing the material down the decline. Heavy populations of rodents dislodge much of the finer soil materials. The slough may nearly fill the horizontal trails, and some finds its way into the gullies.

Wave Action Erosion

Shore lines of oceans and lakes are variously altered by the force of the waves. As the parent material decomposes, wind drifts the lighter particles into bars a few inches to several feet in depth, usually only to be reshifted later, hence revegetation is slow and temporary.

Dune and Dust-Storm Erosion

Low ridges and bars of sand, clay, loam, silt, or peat, which are piled up during dry weather by wind, are known as "wind dunes." As the wind drifts the finer sand, as in the desert, on lake shore, and on prairie, the coarse sand and pebbles remain to form a "desert pavement." Overgrazed pastures and autumn-plowed fields are especially subject to dune and dust-drift erosion (*25*, *26*, *36*, *44*).

Erosion by Water, and Influencing Factors

Of the two major forces of erosion—water and wind—water is commonly the initial offender. "Water-induced erosion" refers to the removal of soil by water as it passes over an exposed soil surface.

The degree of water-induced erosion depends on the geological phenomena of the area, its climatic characteristics, and its biotic factnrs. One or all of these factors prominently influence the transportation of soil by water.

Geological Influences

Slope, aspect, and character of the soils are the most conspicuous geological factors affecting erosion.

Effect of Slope. The degree of slope profoundly and predictably influences the rate of the water flow and its capacity to transport materials. The velocity of flowing water varies with the square root of the percentage of the slope; that is, as the slope is multiplied by 4 the velocity of the water is doubled (*1*). With doubling of the velocity of flowing water its carrying power becomes 32 times as great, for its

carrying power varies as the fifth power of its velocity (Fig 107) When the amount of erosion from a given slope is known, change of the carrying power with change in slope may be used to predict the amount of erosion from a steeper or less steep slope having similar con-

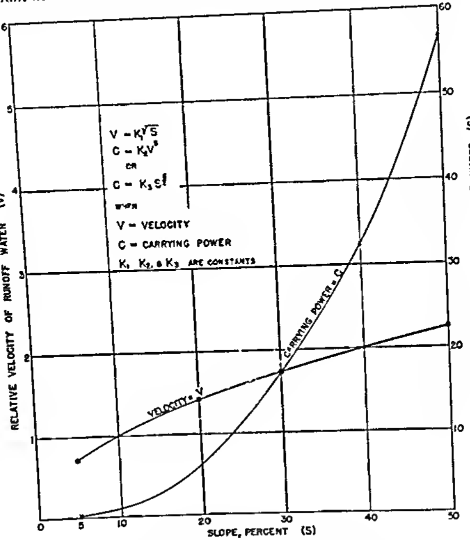

Fig 107 Curves showing relative increase in velocity and carrying power of runoff water with increase in slope

ditions of soil and cover If, for example, under heavy grazing of a 20 percent slope the soil eroded at the rate of 2 tons per acre per year, the amount of erosion from a corresponding slope of 40 percent would be predicted by multiplying the 2 tons by the ratio of the relative carrying powers of the two slopes (Fig 107) The relative carrying power of a 40 percent slope is 32 5, whereas that of a 20 percent slope is 6 5

Thus the expected erosion on the 40 percent slope is $32.5/6.5 \times 2 = 10$ tons per acre per year. Likewise, for a comparable 5 percent slope the indicated erosion would be $0.3/6.5 \times 2 = 0.1$ ton per acre per year. Actual variations in erosion with change in slope might be somewhat greater or smaller than predicted, for the abrasive action of the eroded material, the effects of erosion on the infiltration capacity of the soil, and various slope and runoff relations are not taken into account.

Increased slope reduces the amount of water held in the soil depressions and tends to increase runoff; however, the aerial relations of slope to runoff are modified by the intensity and the duration of the runoff and by the length of the slope. Duley and Hays (*20*) noted that, with increased steepness of slope from 10 percent to 20 percent, erosion increased from 2 tons to 6 tons per acre. Craddock and Pearse (*16*) found that runoff water on a slope of 40 percent transported 3.5 times as much eroded material as on a 30 percent slope. Prolonged, heavy rain storms are likely to cause more erosion per unit area on long slopes than on short slopes, for on the former the erosion power is intensified by the accumulated volume and the resultant increased velocity (*19*).

Effect of Aspect. On western range lands, slopes facing south and west are usually more seriously eroded than north or east facings. Associated with the south or west aspects is a sparser vegetation, less humus and undecomposed plant material, and a more compact soil. Renner (*38*) and others (*40, 43*) strongly urge protection of the more exposed south and west aspects.

Effect of Soils. Some soils are resistant to runoff because of their cohesiveness, and others because of their high permeability. Still other soils may erode so readily as to require special methods of control (*33*).

Coarse sandy or gravelly loam soils are so permeable that runoff and heavy erosion occur only after unusually sharp and heavy rains. But some silts and clays erode readily because of their low permeability, or because of adverse modification of their structure (*22*). Clays such as kaolinite, which do not swell when wetted, are fairly permeable; they tend to erode less than clay soils such as montmorilonite which often form wide cracks when dry but are relatively impermeable when wetted, and erode seriously. *Generally, soils with many water-stable large aggregates are permeable; highly dispersed soils are usually impermeable.* As a rule medium-textured soils erode severely, for they are less permeable than the sands and less cohesive than the clays. Stable soil aggregates tend to prevent erosion, because they are highly permeable and resist dispersion.

Among other stabilizing soil factors are those brought about directly

or indirectly by the vegetation and soil microorganisms. These factors are discussed under "Biotic Influences."

Climatic Influences

Precipitation, wind, and temperature are the primary climatic factors affecting erosion.

Effect of Precipitation. Of these three factors, precipitation—depending upon its kind, amount, intensity, and season—is the most influential in the transport of soils. But the soil-transporting power of rainfall is profoundly influenced by topography, soil type, and vegetation; in fact they compose an inseparable complex. The heaviest erosion on range lands occurs during sharp rains where the litter has been torn asunder and the soil has been compacted by trampling.

Abundant rainfall, by promoting luxuriant growth of vegetation, tends to reduce erosion. Abnormally low precipitation cycles tend to promote erosion by thinning out the vegetation. A range area having an annual rainfall of 10 to 15 inches and requiring 35 to 75 acres to support a cow through the year has poor cover protection against erosion as compared with an area that receives 20 to 25 inches of rainfall and requires only 12 to 35 acres to support a cow yearlong. If, in the region of low precipitation, much of the rainfall comes in sharp showers, runoff and erosion may be particularly severe. Craddock and Pearse (*16*) found that doubling the intensity of rainfall (by means of a sprinkling device) increased erosion by two-thirds. Where much of the precipitation comes as snow erosion is less severe, as shown by Sampson and Weyl (*43*) on high mountain ranges in Utah.

Effect of Wind. The effect of wind on water erosion has not been measured accurately, but driving rains against exposed slopes are known greatly to intensify puddling of the soil. Wind may somewhat reduce soil erosion by bending or flattening the plant growth over the soil surface. More commonly, however, windy rainstorms accelerate rather than retard erosion.

Effect of Temperature. The effect of temperature on water erosion is essentially indirect, being reflected chiefly in its reaction on the vegetation, soil microorganisms, organic matter, and soil moisture. Temperatures that stimulate early spring growth are vitally important after the snow has melted. Also, fluctuating temperatures that alternately cause spring freezing and thawing of the surface soil dislodge the seedlings and induce erosion of the fluffed-up soil. Long periods of low temperatures favor accumulation of organic materials, whereas sustained high temperatures cause speedy decomposition of plant and animal

remains; and high temperatures destroy the microorganisms and lower soil permeability.

Biotic Influences

Vegetation and animal life, including man, constitute the biotic influences. The biota, collectively considered, profoundly affect soil erosion. Fortunately, plant and animal life can be so manipulated as greatly to curb accelerated erosion.

Effect of Vegetation. Plants hasten the formation of soil and increase its organic matter, thereby minimizing soil erosion.

Vegetation provides most of the organic matter (mulch and humus) and tends to maintain a desirable pore space and permeability of the soil. Puddling and clogging of the pores of the soil is prevented (*39*). The roots also help to maintain permeability. Live roots promote the formation of soil aggregates (*5*), so that water flows through the pores formed around the aggregates; and decomposed roots form channels through which water readily flows (Fig. 108).

As the litter comes into contact with the mineral soil, it furnishes food for the microorganisms and various earth-dwelling animals. These creatures help to maintain soil permeability by grinding up the organic matter and working it through the soil. Microorganisms and the many earth-dwelling animals, by working up and turning over the soil and leaving channels through which rain water can flow, greatly increase and maintain soil permeability. Organic matter gives the soil resilience and properties to resist compaction (*4, 5, 9, 12, 13, 17, 21*).

Another important function of vegetation in curbing erosion is the sheltering of the soil from direct insolation and desiccating winds (*47*). The upper layer of exposed soils may get so hot on clear summer days as to destroy the microorganisms and scald the basal stems of invading seedlings (Table 36).

The average maximum surface temperature of 157.4° F. for the four soil series studied accounts in part for the relatively impervious and "lifeless" soils of these denuded areas. In contrast, the average maximum surface soil temperatures of adjoining vegetated areas and of soils covered with only a thin layer of leaf mold averaged 104.7° and 118.0° F., respectively. These vegetated soils were relatively mellow and porous.

Of the various conspicuous influences affecting the soil, none controls erosion better than the plant cover with its litter, roots, and humus (*28*). Weaver and Kramer (*49*), for example, found that, when water was sprinkled over the soil at about 100 times the rate of

normal rainfall, erosion was five to seven times greater when the top growth was removed than when it was left intact Cook (*14*) concluded that vegetation absorbs the kinetic energy of rain before it reaches the ground, thereby mitigating much of its erosive force On

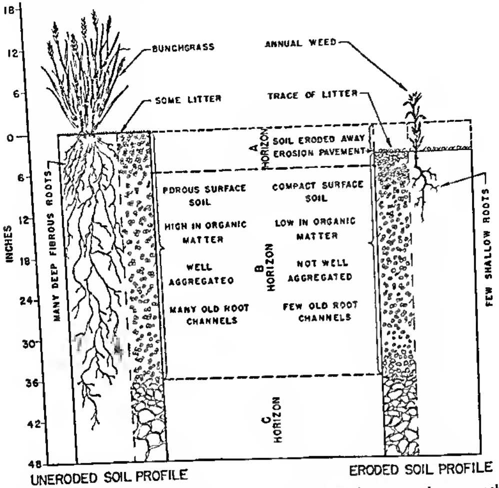

FIG 108 Diagrammatic sketch to show relative root development and top growth of characteristic vegetation on eroded and uneroded soils *Left*, a perennial bunch grass occupying a fairly deep, undisturbed *A* horizon topsoil, *right*, an annual weed growing on subsoil with the *A* horizon topsoil eroded away Note the deeper protective cover of litter on the soil surface to the left

well-vegetated lands a measurable part of the rainfall is intercepted and evaporates into the air, hence little soil is transported Forsling (*23*) reported that a watershed in Utah, the cover of which had been reduced to 16 percent density by overgrazing, eroded heavily, but when revegetated to a 40 percent density erosion was reduced 54 percent On sparsely vegetated Utah ranges runoff and erosion fre

quently occurred after small rainstorms (*10, 40, 43*). Cooperrider (*15*) and others (*41*) concluded that grazing of steep slopes causes erosion approximately in proportion to the character and density of the vegetation. Craddock and Pearse (*16*), working in Idaho, found that a fairly dense stand of native wheatgrass, a perennial species, effectively controlled erosion, whereas a less dense cover of annual weeds was an erosion hazard. Packer (*37*), working with stands of perennial

TABLE 36

Maximum Temperature at Surface of Soil and the Relative Air Humidity Near Noon on Clear Days on Each Site*

Month	*Soil Series*	*Temperature* Surface of Exposed Soil (Degrees F.)	Surface of Soil Shaded by Vegetation (Degrees F.)	In One-Half Inch Leaf Mold (Degrees F.)	*Relative Air Humidity* (Percent)
June	Sites clay loam	154	102	121	22
July	Sites clay loam	161	105	124	17
Sept.	Konockti clay loam	156	106	117	14
Sept	Aiken clay loam	158	104	114	12
June	Aiken clay loam	159	106	119	18
July	Aiken clay loam	161	107	118	15
Aug.	Contra Costa sandy loam	153	103	113	14
Average		157.4	104 7	118 0	16 0

* Data collected by the author on burned vs unburned chaparral lands in Shasta County, California, 1943.

beardless wheatgrass (*Agropyron inerme*) and annual downy chess (*Bromus tectorum*), concluded that either cover was effective in controlling overland flow where the density was adequate. Areas subject to heavy livestock trampling required an appreciably denser cover as protection against soil erosion than undisturbed land.

These cases clearly demonstrate that vegetation is a highly effective factor in controlling soil erosion.

Effect of Man and His Animals. The introduction of domesticated herds and bands on the range increased the pressure that had been exerted by the native animals.

Livestock affect soil erosion chiefly by grazing down the top growth, thinning out and trampling the cover, favoring invasion of annuals or taprooted perennials, and inducing creep erosion by mechanically pushing soil into trails and rills. Craddock and Pearse (*16*), by simulating

trampling, reported erosion increased 1.7 times. Daubenmire and Colwell (*18*) found that virgin prairie soils absorbed water three times as fast as comparable overgrazed land.

Effect of Ground-Inhabiting Rodents. Certain rodents annually deposit large amounts of earth above the surrounding ground surface. Ellison (*21*), working on mountain grassland of clay and loam soils, found that pocket-gopher activity was essentially confined to the herbaceous cover. The gopher disturbed soil was exposed to the elements on closely grazed areas, and the diggings tended to be concentrated in gullies where the soil was readily carried away by rainfall. The extent of erosion resulting from these diggings was approximately proportional to the degree of overgrazing. But there was no evidence that the tunnels formed by pocket gophers caused gully formation on hillsides. Infiltration was apparently increased by the irregularities formed in the soil surface by this rodent.

Erosion by Wind, and Influencing Factors

Drifting topsoil is ripped from the surface by wind when vegetation is insufficient to bind the soil. Wind storms have caused great economic loss by translocating soil made vulnerable by man's unwise exploitation of the land. On the other hand, geologically normal deposition by wind of the finer soil particles has built some of the richest soils in the "granaries of the world" (*26*). The open textured *loess*[1] soils of the midwest corn belt are an example of rich, wind borne soils.

The most powerful influence of wind erosion is the velocity of the wind movement. The flow of sand increases as the cube of the excess of wind velocity over and above the velocity necessary to start the particles moving (*1, 11, 24*). For particles coarser than silt, that is, greater than 0.05 millimeter in diameter, the velocity necessary to start particles moving varies as the square root of the size of the particles. Thus, if velocity doubles, the wind will move grains four times the size of those that were transported under the initial velocity. Wind erosion occurs both as *deflation* (removal of the finer soil particles by shifting or whirling air currents) and by *saltation* (removal of the coarser grains and fragments of soil by a process of rolling or by short leaps).

Material removed by deflation, according to Free (*24*), varies from the finest colloids to particles 1.0 millimeter in diameter. Dust particles blown great distances are smaller than 0.1 millimeter. Saltation

[1] "Loess" soils are unconsolidated, wind laid deposits mostly of silty loams which cover large areas in North America and some other parts of the world, notably in China and southern Russia.

can move much larger particles, such as sand, and even pebbles some 2 inches in diameter. The extent of deflation and saltation depends on both the wind velocity and the physical characteristics of the soil.

Other factors that enter into the extent of wind erosion are temperature, atmospheric humidity, organic matter, slope, exposure, and—most important—the plant cover. Warm, desiccating winds, together with low atmospheric humidity, soon dry out the surface soil and break down its resistance to wind erosion. The organic matter, and to some extent the litter, protect the soil from wind erosion by absorbing and retaining the moisture; and the organic matter tends to form soil aggregates that do not readily erode. Slope tends to facilitate movement of the coarser soil particles when the wind blows down the hill but may retard movement when the wind blows up the hill. The drier south and west aspects with their sparser vegetation are more subject to wind erosion than those of the opposing directions. Vegetation curtails wind erosion by reducing its ground velocity and by the soil-binding action of the roots. The arid grazing lands of the Southwest, especially if overgrazed, suffer excessively from wind erosion because of the sparse vegetation.

By carelessness with fire, unbridled cultivation, road building, mining, logging, excessive grazing, and burning (*15*, *17*, *42*), man has laid waste, through the action of wind and water erosion, to untold acres of range and other lands. According to Utz (*48*), 57 million acres of tillable land, or 14 percent of all cultivated acres in the United States, have been destroyed by erosion. It becomes evident, then, that the biotic influences are, by and large, highly important, because of the loss of soil they may cause.

Erosion and Grazing Capacity

The decline of the western range to less than half its original grazing capacity is clearly correlated with thinning of the vegetation and removal of the topsoil (*1*). Studies in Utah revealed that native brome produced barely half as much forage on eroded as on noneroded range soils (*43*). Sinclair and Sampson (*46*) found that the water requirements were measurably higher for range grasses grown in areas whose topsoil (horizon *A*) had eroded away (Fig. 109). These workers concluded:

> The removal of the *A* horizon tends not only to decrease the luxuriance of growth of the vegetation, but greatly retards, if it does not actually prevent, the reestablishment of the climax and subclimax plant cover.

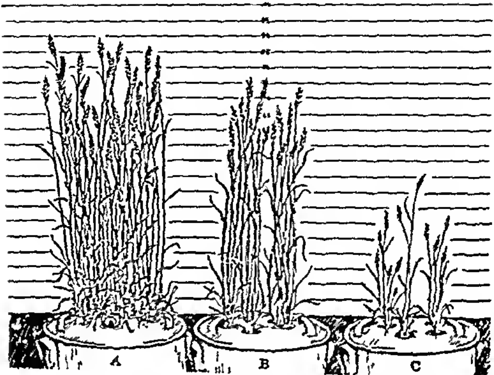

FIG. 109 Wheat grown in *A*, *B* and *C* horizons of the Holland soil series, California Soils were artificially packed Measurably *more water was required* to produce a unit of dry weight of plant material on horizon C, and slightly more on horizon *B*, than on horizon *A* Note relative size of plants on the three horizons The plantings were made simultaneously *[After Sinclair and Sampson (46)]*

Erosion and loss of soil nutrients are inseparable Bennett (*6*) estimated that loss of soil nutrients by erosion is 21 times as great as the amount of nutrients removed from the soil when the crops are harvested Various legumes yielded from 50 to 100 percent less on eroded than on noneroded soils

Nearly everywhere over the western range country the vegetation has been thinned The exposed, clogged, and compacted subsoil has curtailed infiltration of rainfall and intensified runoff As the gullies have deepened the water table has dropped, depriving the climax vegetation of its normal moisture supply Gradually, various annual plants, most of them low in palatability and nutrition, replace the perennials, the mainstay grazing plants Certainly the facts warrant the effort of curbing a destructive rate of erosion

Erosion Control on Pasture Lands

The principles involved in the control of erosion on range lands are essentially the same as those for farm lands and watersheds. Controls

consist chiefly of reestablishing the cover with palatable, effectively soil binding plants and, in the more aggravated cases of the building of mechanical structures (*50*)

Vegetal Control

Where the soil is still fairly productive, mere revegetation of the area is the most practical means of controlling water and wind erosion Bailey (2), for example, found that vegetation stabilized fine textured soils even on a slope of 60 degrees The steeper the slope the more important it is to maintain a vigorous vegetation This may be done by artificial or natural reseeding (Chapters 11 and 12)

Mechanical Control

Where numerous deep gullies have been formed and vegetation is inadequate to stop erosion, mechanical obstructions must be established to break the force of the surface runoff This is accomplished by build ing terraces, contour furrows and check dams, and by water spread ing (*32*) Greatly improved techniques in establishing these devices have been advanced by the Soil Conservation Service (*6*)

Terracing In steep country of heavy precipitation, terraces or 'ridges have been constructed to divide long sloping areas into several small units primarily with the idea of draining off the excess precipita tion The terrace channel, being from 2 to 5 feet wide and built on low grade, slowly conducts the runoff to a well protected outlet, much of the water so caught is absorbed, thereby favoring revegetation this ing the water table, affording protection to the soil, and stabilizing stream and spring flow Terraces are most popular in the humid East where they are placed from 15 to 25 feet apart, according to the topography and local needs Occasionally terraces are partitioned at intervals of 25 to 50 feet to increase absorption of the water and to guard against damaging breaks of a long nonpartitioned terrace The cost of terracing varies from about $2 50 to $6 00 per acre, which makes it less popular than contour furrowing on low valued western ranges (*25*)

Contour Furrowing Range lands in relatively low rainfall areas are often greatly benefited by contour furrowing (*35*) As moisture is conserved and erosion minimized, the range forage becomes denser and improves in quality In Texas Langley and Fisher (*29*) reported that three times more rain was absorbed on furrowed range, that the forage yield increased nearly five times and that erosion decreased considerably In Utah Bailey (2) found that an 80 acre contour furrowed and reseeded watershed produced no runoff during exceedingly high and

intensive rainfall, whereas, on a similar untreated area of only 15 acres, 28,234 cubic feet of runoff was recorded

The furrows may best be maintained by an abundant plant cover They should be about 10 inches wide and 6 inches deep and spaced 3 5 to 7 feet apart The cost of such furrowing varies from about 50 cents to $1 50 per acre

Soil type, slope, kind of plant cover, and favorableness of the growing season largely determine the success of furrowing Heavy-textured soils that absorb water slowly are benefited most, sandy soils the least, very fine sandy loams being on the dividing line of suitability (*31, 32, 34, 35*) Heavy soils that have been compacted by trampling and that are low in surface organic matter are especially in need of furrowing Slopes of 1 to 15 percent have been measurably benefited, but the more gently sloping areas respond best as the water spreads more evenly (*31, 34*) Unless the steeper slopes are well vegetated when the furrows are constructed, they are likely soon to fill up with eroded soil before revegetation can take place

The native plant species present greatly influence the returns from range land furrowing In the southern Great Plains region, buffalo grass and blue grama do not grow so rank as to become unpalatable, but side oat grama and tobosa grass are rejected by stock because of their coarse growth If erosion is severe, furrowing is justified despite the coarse plant growth Where artificial range reseeding is done after furrowing, the less robust species should be used

Various implements and types of contour furrows have been used with success The implements and the techniques of furrowing are fully discussed by Ayres (*1*), Bennett (*6*), and Gustafson (*25*)

Check Dams Where terracing and furrowing are inadequate to protect critical areas, temporary check dams made of brush, loose rock, poles, or wire are sometimes effective Temporary, low check dams are soon stabilized by the invading revegetation Small check dams are especially effective in leveling out gullies of small land units, but permanently constructed dams are needed to control gullies of large watersheds where well-secured waterways must be maintained Permanent dams may also furnish water for livestock These, commonly, are built of concrete, metal, or earth

Water Spreading This term implies diversion of water from natural drainage channels to small check dams, ditches, or furrows from which it can be liberated gradually over the range The practice is adapted to the smoother grazing lands where precipitation is low and erosion is on the march Closely spaced contour furrows and ridges are especially recommended across the upper end of gullies of critical areas

Slopes with gradients up to about 7 percent may be irrigated by water spreading (*31*). Slopes having the maximum gradient should receive special treatment. According to Bennett (*6*):

> Furrows for retaining, rather than conveying, water usually are turned upslope as gullies or natural depressions are approached, in order to close the ends. . . . Thinning of dense stands of sagebrush, combined with the use of the brush to build contour percolators, is giving excellent results in eastern Utah and western Colorado.

Regardless of the efforts made to control erosion by vegetation or mechanical structures, little will be accomplished unless certain recognized range practices are applied.

Cardinal Points of Range Management in Erosion Control

The need of maintaining the range forage at or near maximum production of the capability of the land is imperative to continuous economic livestock production and to conservation of the soil and the water. Achievement of this aim requires rational planning at all times. The following points should be checked against decline or adverse change in the forage cover and should be followed by a correction program.

1. Where ample seed plants remain, reestablish a thinning stand of forage and browse plants by natural reseeding. Deferred-rotation (Chapter 12) grazing is economical and effective in curbing erosion.

2. Where the soil is so exposed that only a scattered stand of the choicer forage and browse species is left for seed production, artificial reseeding may expedite reestablishment of the cover (Chapter 11).

3. Grazing by the wrong class of stock is responsible for damage by erosion in some areas. Cattle do best on level or moderately rolling areas. In rough country cattle concentrate on the meadows to the extent of thinning out the cover and starting gullies. Sheep do well in the steeper country and can usually be kept from overgrazing the more accessible areas. Goats are especially suited to utilize brushy ranges (Chapter 15).

4. Conservative grazing should be practiced, with due regard for the proper beginning and ending of the grazing season and desirable distribution of the stock (Chapter 14).

5. Protect the cover against fire. Grassland needs an adequate stubble and leafage to protect the old plants through the winter and the seedlings in the spring from damaging frosts and soil heaving. The soils of burned grassland, like those of overgrazed areas, are subject to severe erosion. Also, the steeper slopes of brush-covered areas should be protected from fire to prevent erosion (Chapter 13).

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Chapter 24

ADMINISTRATION OF PUBLIC GRAZING LANDS

The Federal government still owns some 412 million acres of public land in continental United States and 365 million acres in Alaska. Although not all these lands are grazed, the acreage cropped annually is so large that its sound administration is important to stockmen and the nation as a whole.

The objectives of public range-land administration are: (1) to insure sustained forage production and maximum grazing use based upon estimation of grazing capacity, establishment of rational grazing periods, and selection of the most suitable kind of livestock for the plant cover, soil, and topography; (2) to obtain a balanced use of the resources by preventing one use from causing undue damage to the other resources; (3) to stabilize the livestock industry by recognizing the eligibility of permittees, issuing long-term permits, and granting maximum freedom of operation; (4) to render technical assistance to the grazier and prevent inequality among permittees on Federal range.

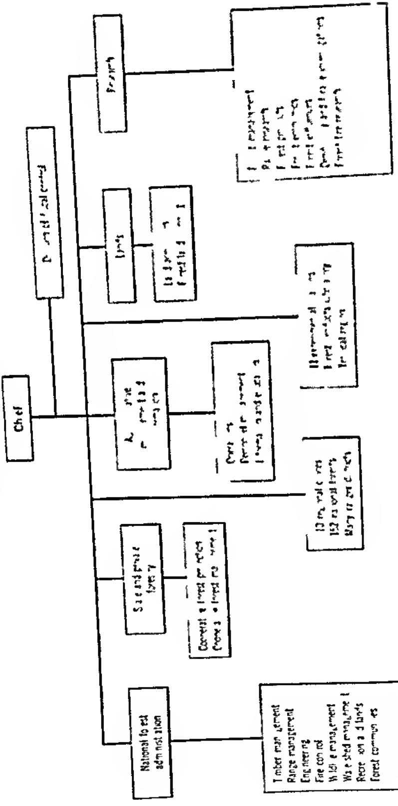
Lands administered by the Federal government are shown in Table 37 (*26*).

Of the Federal administrative land agencies, the Forest Service, the Bureau of Land Management, and the Indian Service administer most of the public grazing lands. In addition, the Soil Conservation Service cooperates in the improvement of public lands where such areas are included in their official districts. Discussion of the land administration is therefore centered on these organizations.

National Forest Administration

The Forest Service is organized on a regional basis, with the Chief Forester's office in Washington, D. C. (see Organization Chart 1). There is a Division of Range Management (*18*) in the Washington office and also in each of the six western regional offices (Fig. 110). On the national forests there is usually a staff assistant in charge of range management under the direction of the forest supervisor. Each

ORGANIZATION CHART 1
UNITED STATES FOREST SERVICE
Department of Agriculture*



* Adapted from U S Dept Agr Forest Service 1944 (13)

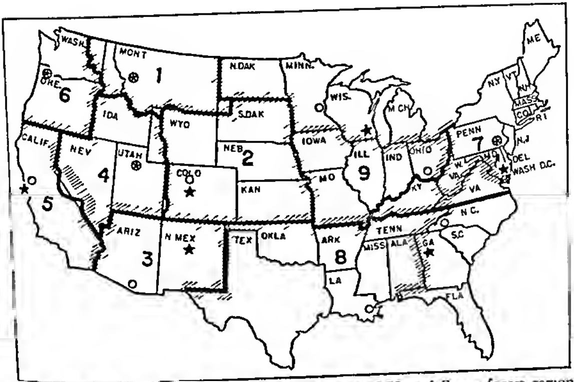


Fig. 110. Headquarters and territorial boundaries of United States forest regions and experiment station work areas, Forest Service. ▬ Regional boundary. //// Experiment station boundaries.

★ *Regional Headquarters*

Region 1, Missoula, Mont., 17 national forests

Region 2, Denver, Col., 17 national forests

Region 3, Albuquerque, N. M., 13 national forests

Region 4, Ogden, Utah, 20 national forests

Region 5, San Francisco, Calif., 18 national forests

Region 6, Portland, Ore., 19 national forests

Region 7, Philadelphia, Pa., 7 national forests

Region 8, Atlanta, Ga., 27 national forests

Region 9, Milwaukee, Wis., 11 national forests and purchase units

Region 10, Juneau, Alaska, 5 national forest divisions

O *Experiment Station Headquarters*

Northern Rocky Mountain, Missoula, Mont.

Rocky Mountain, Fort Collins, Col.

Southwestern, Tucson, Ariz.

Intermountain, Ogden, Utah

California, Berkeley, Calif.

Pacific Northwest, Portland, Ore.

Northeastern, Upper Darby, Pa.

Southeastern, Asheville, N. C.

Southern, New Orleans, La.

{ *Lake States*, St. Paul, Minn.
{ *Central States*, Columbus, Ohio

national forest is divided into districts and each district is in charge of a ranger. The ranger is responsible for the administration of grazing on his district, under the guidance of the forest supervisor through the staff assistant. The districts are further divided into grazing allotments according to topography and drainage.

The primary policy of the Forest Service is to conserve the resources under wise use rather than preserve them (*15*). The chief forester is directly responsible to the Secretary of Agriculture, the regional forester to the chief forester, the supervisor to the regional forester, and the ranger to the supervisor.

Advisory Boards

The formation of associations of grazing permittees is encouraged by the Forest Service. Many are active and helpful on ranger districts or on other subdivisions of the forest.

Advisory boards in many instances are elected by each association for their respective area, and delegates from these are elected to the forest advisory board representing both cattle and sheep permittees (*14*). In 1948 there were some 800 advisory boards (*15*).

Grazing Permits

In 1948 the Forest Service issued 18,504 charge permits for part-season grazing of 1,153,246 cattle (exclusive of calves under 6 months of age) and 3114 charge permits for part time grazing of 3,321,993 sheep, exclusive of lambs (*16*). Stockmen who desire a permit must submit applications to the supervisor, who considers their qualifications by following the rules and regulations in the *Forest Service Manual* (*14*).

Most forest range can be used effectively only by persons owning suitable land nearby that enables them to receive a balanced, year-around forage supply from both the private holdings and the forest range. The eligibility of applicants is therefore largely determined by their "dependency" and "commensurability."

Dependency concerns the extent to which private and public lands are interrelated in the economic use of their resources, especially feed and water. Dependency is governed by the need for national forest range—generally summer range—to round out an operation so that proper and practicable use can be made of the base (home) property. An operator who lacks the kind of range that is available on the forest and that he needs for practical and efficient over-all operation is recognized as dependent to the extent of his needs. Generally, a home

ranch near the national forest is given preference over one more remotely located.

Commensurability, or commensurable property, is the measure of the applicant's capacity to take care of the livestock on his own land or leased property while not on national forest range. The conversion factor for sheep is computed at 5.0 sheep per cow. An operating owner of a ranch on which the animals can be carried during the season

TABLE 37

LANDS ADMINISTERED BY THE FEDERAL GOVERNMENT

Land Units	*Administrative Agency*	*Acres Administered* U. S	Alaska
National forests	Forest Service, Dept Agr.	160,000,000	21,000,000
Grazing districts	Bur Land Management, Dept Interior	151,700,000	
Vacant, unappropriated, and unreserved public lands outside of grazing districts	Bur. Land Management	36,000,000	
Indian reservations	Bureau of Indian Affairs, Dept. Interior	56,000,000	3,000,000
Military reservations, bombing ranges, etc.	Dept Natl Defense	18,000,000	32,000,000
National parks and monuments	Park Service, Dept. Interior	16,000,000	7,000,000
Other reservations	Various agencies*	16,000,000	32,000,000

* Small parcels of public lands are administered by the Bureau of Reclamation, Soil Conservation Service, Fish and Wildlife Service, and some other Federal agencies

when the forest range is not available is given preference over one who purchases or rents his feed for that period. The eligibility ratings are of great importance, because in most localities the numbers of stock the applicants would like to graze far exceed the forage supply.

Permits are classified as term, annual, temporary, free, on and off, private land, or crossing.

Term permits, mostly issued for a period of 10 years, are granted to especially qualified applicants.

Annual and term permits each denote a "preference." If an operator is eligible for an annual permit he is also eligible for a term permit when he so requests.

Temporary permits are issued to applicants for surplus range according to priority, extent of ownership of livestock, the extent of existing permits, commensurability rating, and certain other facts

Free permits may be issued to bona fide settlers for not more than

10 head of animals used for domestic purposes, to prospectors, campers, and travelers for number of head actually in use, to pack outfits, and for special concessions to Indians

On and off permits are issued only where movement of the permitted livestock is necessitated between national forest land and adjoining outside range, or where private and forest lands are intermingled

Private land permits are issued when the government is compensated for use of forest lands by the use of private lands of equal value, and when lands are released to the government for exclusive administrative control of the grazing use

Crossing permits may be issued to persons desiring to drive livestock across any portion of a national forest for legitimate purposes

How Preferences are Acquired

A preference conveys no legal right but merely gives the holder special consideration over other applicants Preferences are acquired by prior use or occupancy, by local residence and ownership of com mensurate property with temporary use of the range for 5 consecutive years, by renewal of a permit formerly held in partnership or in a corporation, by purchase of a permittee s stock or ranch or both, by inheritance, and by being a citizen of the United States

High consideration is given to resident home builders, since by using the national forest range along with their personally owned range and crop lands they are better able to round out effective yearlong opera tions (*15*) Vested (property) rights are not recognized (*12*), a con dition contrary to the much criticized European policy

Lower and Upper Limits

To secure an equitable distribution of grazing privileges, to prevent monopoly in the use of national forest range, and to aid in stabilizing the livestock industry, the forester establishes *lower* and *upper* limits in permitted numbers of livestock (*19*) The lower limits rule is designed in general to the economic level for the average family unit It is also the limit below which no reductions will be made in his permit for further distribution of the grazing privilege The upper limit is the number of livestock up to which permits may be issued or con solidated through the purchase with waiver procedure Generally, this is at a level of optimum operating efficiency without monopoly In the California region the present lower limits are 200 for cattle and 1000 to 1250 for sheep the upper limits from 400 to 500 for cattle and 2500 to 3000 for sheep

Grazing Fees

The forest service has established base fees, which vary with the quality of the forage and the cost of operation on the individual range allotment. The fees were derived from a study of grazing-land rentals in western United States. A base price of $6.62 per hundred pounds for beef and $9.15 for lambs was derived from the market prices during 1921 to 1930 and 1920 to 1932, respectively. Based on these periods, the calculated monthly fees per head nationally averaged 14.5 cents for cattle and 4.5 cents for sheep (*14*). The annual fee is calculated by multiplying the base fee by the ratio of last year's market price to the base price. For example, if the average market price received by cattlemen in the 11 western range states last year was $19.86 per hundred pounds, then the fee for the current year would be 19.86/6.62 × 0.145, or 43.5 cents per month. The base fees have been adjusted somewhat on the various national forests and on allotments within a forest, depending on quality of feed and cost of operation. The base rates are worked out in conjunction with the livestock associations and, if possible, with their approval.

Fees for goats are the same as for sheep; for horses the base fee is 125 percent and for swine 75 percent of the 1931 base for cattle. The 1949 fees averaged about 49 cents per month for cattle and 11 cents per month for sheep (*16*). Since the fees on the national forests are intended to approximate the value of the forage, the base period may be expected to change with changes in economic factors.

The money collected for grazing and other cash returns from the national forests goes to the U. S. Treasury. An amount equal to 25 percent of all receipts is paid to the counties containing national forest lands for expenditures on local roads and schools, prorated according to county acreage in national forests. An additional 10 percent of the receipts is allotted for expenditures on national forest roads in the states of origin.

Other Regulations

Grazing regulations not previously mentioned, as given in Volume 3 of the *Forest Service Manual* (*14*), concern the following: (1) establishment of grazing allotments, prescription of the number and class of stock to be grazed, and period of grazing on each allotment; (2) collection of grazing fees; (3) provision for proper range management and range improvements; (4) enforcement of sanitation, quarantine, and other local laws; (5) cooperation between stockmen and administrators in all matters of mutual interest; (6) provision for management of wild-

life and other uses, (7) control of trespass by stock, impounding animals, and collection of resulting damages, (8) provisions for range surveys and grazing investigation

In its 45 years of range management the Forest Service has, on the whole, established an enviable record, and many of its policies and practices have been adopted by other public-land agencies

Range research has been instrumental in shaping the management policies adopted on the national forests (*16*) Range-research organizations are located in each western forest region (Fig 110) Their aim is primarily to clarify problems that are especially vexing to the administration Cooperative range research is also carried out with other Federal agencies, state agricultural experiment stations, extension services, and some private stockmen

Administration of the Bureau of Land Management

Up to the passage of the Taylor Grazing Act of 1934 the grazing districts of the ten western range states were the leftover "free for-all" grazing commons They were severely overgrazed The administration, since the Act of 1934, has resulted in an improved condition of some of the vast area, but the Grazing Service has been handicapped, largely because of lack of technical and administrative personnel On July 16, 1946 (*20*), the Grazing Service was merged with the General Land Office to form the Bureau of Land Management (see Organization Chart 2)

So unsettled were conditions in 1946 and 1947 that several of the district graziers (now called range managers) were retained only through the generosity of the local advisory boards[1] Yet progress has been made, especially in the establishment of allotments for individual producers and in initiating various range improvements In 1948 approximately 20,000 livestock operators were licensed to graze some 3 5 million cattle and 9 million sheep within grazing districts for a part of the year (*1*)

Currently, both the district lands and the "section 15" lands[2] (*9*) are administered by the Bureau of Land Management (Fig 111) The recent decentralization of administrative decisions from Washington, D C, to the western field headquarters has expedited processing range-use applications and other vital matters (*20*) Also, if the personnel were

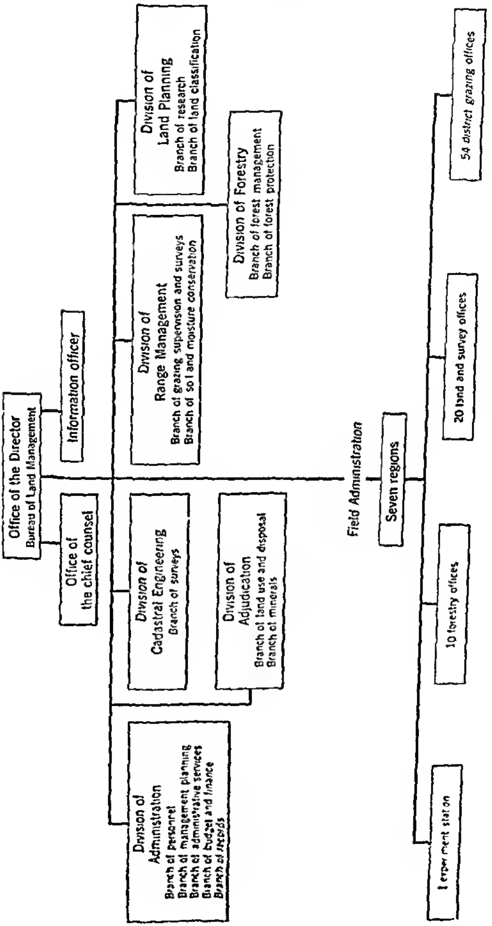
[1] District advisory boards are considerably more influential than national forest advisory boards

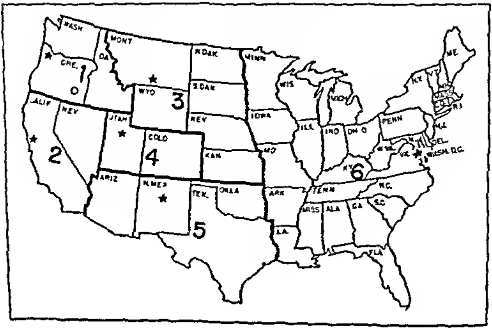
[2] "Section 15" lands are those vacant, unappropriated and unreserved public domain areas that are not included in the grazing districts but that are leased for grazing as authorized by section 15 of the Taylor Grazing Act (*24*) In 1948 12,210 992 acres were so leased (*21*)

ORGANIZATION CHART 2

BUREAU OF LAND MANAGEMENT

Department of the Interior

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Administration of these lands is guided by the rules and regulations contained in the *Federal Range Code* (*24*), a publication similar to the grazing regulations in the *Forest Service Manual* (*14*).

The regulations provide that preference in the granting of grazing privileges be given to the old established land-owning stockmen living within or near a district. The aim is to permit proper use of their own lands, any water or water rights owned, and to insure effective use of occupied or leased areas. Temporary licenses, usually for 1 year, or term permits for 10 years are issued as the case may justify. The bureau favors long-term permits for all qualified users. In 1948 about one-half of the Federal range users within grazing districts were under 10-year permits (*21*).

The fees are much lower than those on the national forests and are determined by the minimum cost of administration rather than by the full value of the forage. Effective August 6, 1947, the charge for cattle and horses per animal unit month was set at 8 cents, for sheep and goats 1.6 cents (*24*). This charge is divided as follows: established grazing fees (to cover bare administrative cost) for cattle and horses 6 cents, for sheep and goats 1.2 cents; a range-improvement fee for grazing of cattle and horses 2 cents, for sheep and goats 0.4 cent. Since the grazing-fee figures are essentially based on the cost of administrating the grazing, the district advisory boards have recommended an increase in grazing fees in the interest of improved range management. The fees collected on the districts go to the U. S. Treasury. But 12½ percent of the 6 cents grazing fee for cattle and horses and the 1.2 cents grazing fee for sheep and goats is returned to the state for use in the county or counties in which the district is situated. The local governments may also receive various hidden benefits from range improvements made possible by the range-improvement fee.

"Section 15" lands are let by lease for grazing purposes rather than by issuance of grazing permits. The leases may be issued on a yearly or a 10-year basis. The charge depends on the quality of each tract, and is in no case less than $1.00 per annum for a given parcel of land. The charge is usually between 3 cents and 5 cents per acre a year, but for the poorest land it may be less than 1 cent, for the best land as high as 44 cents (*25*). Preference is given to qualified applicants under similar general regulations as those for grazing-district applicants.

Prior to 1934, administration tended to force the Indians to accept the white man's mode and standard of living including the principle of individual land ownership. Under a succeeding policy in the Allotment Act of 1887, each Indian was given a piece of land clearly insufficient to support a family. The Indians would sell the timber, forage, and frequently the land too. The white man purchaser seldom applied rational management to the resources, since there were no provisions for conservation.

Most Indians were forced to seek a living away from the land; the few who kept their land subdivided it among their heirs and ownership became confused. Between 1887 and 1939 Indian owned lands decreased from 138 million acres to 50 million acres (*20*, *27*).

In 1934 (*22*) the Allotment Act was replaced by the Indian Reorganization Act also known as the Wheeler Howard Act. Its primary objectives were: to conserve and develop Indian lands and resources, to extend to Indians the right to form business and other organizations, to establish credit for Indians, to provide for vocational education for Indians (*11*). It also restricts further alienation of Indian land and provides for consolidation and acquisition of Indian lands. Section 6 provides for proper range management practices.

The Indian Reorganization Act has helped solve the intricate Indian situation much as the Taylor Grazing Act has shown how to cope with problems of the western range. It has resulted in improvements such as fences, roads, wells and springs, erosion control, and control of wild horses.

Before its passage the Indian stock industry was of little importance. But in 1934–35 the Federal government issued 42,100 head of cattle to the Indians.

The more influential regulations governing the use of Indian grazing lands are as follows (*3*, *4*): (1) The lands have been set up into natural grazing allotments. Except on allotted lands, the commissioner of Indian affairs prescribes the maximum number of stock to be grazed according to the carrying capacity of the range based on utilization surveys. (2) Permission to use Indian lands for grazing is granted by permit. The Tribal Council or its representative is authorized to designate who will graze livestock, the number and kind of stock, the charge if any, and the duration of the permit, not to exceed 5 years. (3) The acreage grazing share of an Indian is determined by the total acreage available and the number of members in the tribe. (4) Group rather than individual permits are recommended chiefly to facilitate the carrying out of range management plans and improved livestock handling. (5) If necessary, the Commissioner of Indian Affairs may

revise a grazing permit, without consent of the parties, to regulate the range properly.

Soil Conservation Service

The Soil Conservation Service cooperates with public land agencies such as the Forest Service, Indian Service, and Bureau of Land Management, where public lands are included in its districts. In such instances the work is carried out by cooperative agreement among the agencies.

The main objective of the Soil Conservation Service is to promote control of soil erosion and encourage better use of farm and range land. Up to 1935 the work was done by the Soil Erosion Service, an emergency agency in the Department of Interior. In that year the Soil Conservation Service was transferred as a permanent agency to the U. S. Department of Agriculture.

National headquarters are in Washington, D. C. But offices are established in every state of the union and the territories, to carry out the various programs and activities of the service, largely on private lands. For purposes of administration, the United States has been divided into seven geographical regions, each with a regional director in charge (see Organization Chart 3).

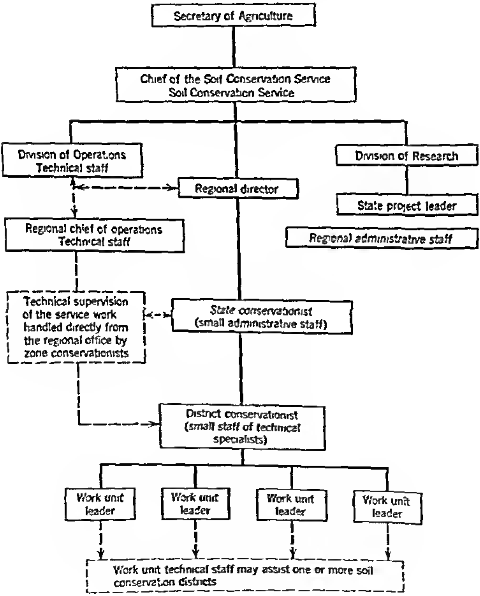
The Soil Conservation Service provides soil- and water-conservation technicians to assist farmers and ranchers in soil-conservation districts to carry out, at their request, a sound soil- and water-conservation program, which has been developed for the various regions. All 48 states and the territories have soil-conservation district rules under which landowners may organize. A soil-conservation district may be formed by a vote of landowners within the designated area and is usually governed by five elected landowners living within the district. Interest in range conservation is constantly increasing, and more and more soil-conservation districts are being formed in range country.

Basic to the assistance that is rendered to the ranchers in soil-conservation districts is the classification of the land according to its capabilities. Primarily, the classification indicates the intensity and kind of use to which particular lands may be safely subjected. Such a classification indicates broadly the several levels of sustained production that the rancher might be able to attain on the various parts of his range, and it provides the basis for integrating the grazing use of different kinds of land in a livestock program.

The cooperating rancher is provided with technical assistance in making utilization checks, developing needed water supplies, selecting the best sites for range improvement, developing water spreading, contour furrowing, pitting, and seeding improved forage plants adapted to

ORGANIZATION CHART 3

Generalized Organization Chart of the Soil Conservation Service United States Department of Agriculture



the area. In many cases it is possible to assist the rancher in developing small but important additional supplies of water to provide extra feed in the form of irrigated pastures or hay for his livestock.

Soil and water conservation on range lands is achieved largely through improvement of the forage cover. Special emphasis is placed on proper range utilization. The operator must not only obtain the most practical distribution of his animals on the range but must also maintain the key forage plants in a strong state of vigor. To accomplish these things he is given various indicator guides for judging favorable or unfavorable trends in his range condition.

State and County Grazing Lands

Several western states administer some grazing land. Most of these areas consist of scattered tracts (*5*). Many local stockmen speak of any state land as "school land." This may or may not be correct, because grants were made to the states for various kinds of public institutions and projects, as well as for the support of school systems. Some 225,000,000 acres were granted to the states from the public domain (*26*). Several of the states, Kansas, Nevada, California, Oregon, and Oklahoma, have disposed of most of their grants. Others, Arizona, New Mexico, Washington, South Dakota, have retained a large part of theirs (1). In 1941 the states still owned some 55,000,000 acres of their granted land; in addition, approximately 100,000,000 acres reverted to state or county governments from private ownership (*13*). Only a small percentage of this land is suited for uses other than grazing.

The administration and management of these lands vary from state to state and county to county. Before effective administration can be provided, a physical and economic inventory must be made. Since inventory surveys are expensive few states have made them, even where authorized by legislation.

Montana has been especially successful in working out its public land program by establishing state grazing districts as authorized by the Grass Conservation Act of 1939 (*13*). The districts are cooperative organizations whose membership is voluntary and limited to livestock operators. It is the duty of the Grass Conservation Commission to require the districts to comply with the regulations set up.

Security of tenure on state lands is increased if the lessee is granted the first right to purchase when the land is offered for sale. But, if the operator is not in a position to purchase the land when offered, he is better off if the land he leases is not subject to sale.

Under the South Dakota Land Management Act lands are classified as suitable for immediate sale, or for sale only at long intervals and upon

reclassification (*13*) The charge for leases is computed as by the Forest Service, the rental scale being based on the market price for livestock and livestock products

Many of the western states charge a fixed rental for a parcel of grazing land In most instances the charge is several cents more per acre than for similar "section 15" lands administered by the Bureau of Land Management

Conflicts in Grazing Use of Public Lands

Both major Federal agencies administering public-domain range, the Forest Service and the Bureau of Land Management, are operating under basic laws set up by acts of Congress

The Forest Service has long been guided in its administration by researchers of the range, timber, watershed, and game resources Although its administration seems to be sound, a small group of articulate stockmen have vigorously challenged its management policies. Most of the conflict stems from the principle of multiple use management of the national forests they provide forage for domestic stock, produce timber and needed wood products, and have high value as watersheds, as recreation areas, and for game production Since most of the Bureau of Land Management lands are primarily useful for grazing, they are but indirectly involved in the stockmen s opposition

The principle of coordinated maintenance and use of all the resources on the national forests was stated by Secretary James Wilson in his letter to the Chief Forester under date of February 1, 1905

> Where conflicting interests must be reconciled, the question will always be decided from the standpoint of the greatest good of the greatest number in the long run

With this basic principle the grazing policies have developed as follows (*15*) (1) preference is given the home builder, (2) long-term permits and renewal preferences are provided as a step toward the stability of livestock operations, (3) monopolistic and uneconomical operations are guarded against by the establishment of lower and upper livestock limits, (4) an equitable grazing fee is charged for grazing privileges, (5) adjustments in permitted numbers of livestock, when necessary, are made gradually, so that the permittee may plan his operation accordingly

Although grazing is encouraged on suitable national forest lands, the forage in many instances has declined because of encroachment of tree and brush growth The mountain meadows, which in earlier years supported large numbers of stock, are in poor condition due to over

grazing. Also, critical watersheds have had to be grazed more lightly, which led to a gradual reduction in livestock numbers on the national forests. For the 30-year period (1918 to 1948) total animal units grazed on the national forests in the western states decreased 53.2 percent (*10*). This decline in livestock numbers—and the simultaneous sharp increase in the numbers of antelope, deer, and elk—caused the graziers to challenge the multiple-use policy of the forest service. According to Kelso (*8*):

> Out of this very [multiple use] device part of the conflict over western Federal land management arises. Grazing is reduced in the interest of watershed protection and water yield. Why should we expect him [the grazier] to do otherwise unless he is motivated by a larger fund of "social consciousness" than are most of us? . . Stockmen want more grass, lumbermen want more trees, recreationists want more timber and game, irrigationists want their water in regular flows without floods or shortages.

Somehow the manager of public multiple-use lands must try to balance the use of one resource against the others. More recently the question has been raised: Why should not these lands be placed in private ownership? Or, why should not the stockmen control the grazing administration of these lands?

The proposal of private ownership is untenable chiefly because: (1) low grades of western grazing lands are more over-assessed with respect to capitalized net earning value than the better lands (*10*); (2) multiple-use lands would be abused in the interest of the grazing resource; (3) many areas do not lend themselves to subdivision for single-operation control but must be used in connection with privately owned lands or with lands controlled by other Federal agencies.

Certainly private ownership is not the answer to a balanced use and conservation of the public range lands. Even if these lands were made available for private filing, the major portion would likely remain in public ownership.

Some students of land management have suggested that a new administering board be set up, representing both the user and the administering agency (*8*). This board should meet frequently enough to be abreast of the local problems and should be empowered to make decisions binding on both parties.

One of the greatest needs in clarifying proper use of both public and private range lands is a far-reaching educational program. Few stockmen understand how a range-inventory or -management plan is made or which plants provide the most or the best feed. Still fewer recognize the different range-condition classes or what constitutes proper stand-

TABLE 38

COMPARISONS OF CHIEF PUBLIC GRAZING ORGANIZATIONS AND AIMS

Forest Service	Bureau of Land Management	Indian Service
Area Administered		
160 000,000 acres,* about 85,000,000 acres grazed annually in 11 western states	151,700,000 acres,* mostly grazed annually	56,000,000 acres, 42,000,000 acres grazed annually
Location		
Medium to high forested mountains and grassy glades, mostly in the West	Arid western country, medium to low elevations, little timber, *few recreation sites*	Widely scattered throughout the West, diversified seasons *of grazing use*
Time of Creation or Acquisition		
Forest Reserve Act of 1891, lands mostly under intensive administration by 1905	Taylor Grazing Act of 1934 set aside 80,000,000 acres, amended act of *1936* provides for 62,000,000 additional acres or the maximum of 142,000,000 from public domain	At various times during Colonial days, by treaty and by executive order of allotments from 1887–1934 Wheeler Howard Act of 1934 was designed to develop and manage these lands
Purpose of Administration		
To conserve and rationally use timber, forage, water, game, and recreation values	To develop, improve, and stabilize the grazing industry, *conserve and* build up all renewable resources	To provide industry as a means of livelihood for Indians, and to *conserve* resources
Where Administered		
Department of Agriculture, grazing control since *1905*	Department of Interior, authority given in 1934	Department of Interior since 1910, an effective policy *only since 1934*
Character of Lands		
About 80 *percent summer* range, balance spring fall and winter range, much rugged topography, important watersheds	Much yearlong range at intermediate elevations, grazing capacity moderate to low	Yearlong *and spring fall* range, considerable waste land, grazing capacity intermediate
Grazing Charge		
Cattle 14 5¢/head/mo base fee, adjusted on basis of livestock prices Cattle fee averaged 49¢ in 1949 Sheep 4 5¢ base fee, with 1949 average fee of 11¢, based on value of forage	For cattle 6¢/head/mo, sheep 1 2¢/head/mo, range improvement fee, cattle 2¢/head/mo, sheep 0 4¢/head/mo., total charge, cattle 8¢/head/mo, sheep 1 6¢/head/mo, based on minimum administration cost	Representative of Tribal Council advised by superintendent, and regional forester determines charge

* These figures include lands acquired by purchase, exchange, and cooperative agreement. Excluding these, the *Forest Service administers 139,000,000* acres on the national forests, the Bureau of Land Managrment 142,000,000 acres in grazing districts *(17, 21)*

TABLE 38 (*Continued*)

Forest Service	Bureau of Land Management	Indian Service
Disposal of Fees		
25 percent to states in which lands are located; 10 percent for forest roads in states of origin; 65 percent retained in U. S. Treasury	12.5 percent to states in which lands are located; remainder to U. S. Treasury	Paid to tribal representative for distribution to qualified Indians; a portion reserved for range improvements
Range Experiment Stations		
1 in each of 6 forest regions of West; 2 in southeastern states	One cattle range experiment station at Squaw Butte, Burns, Oregon, conducted in cooperation with Oregon State College, Corvallis	None
Game Population		
Some 75 percent of big game in western states spend much of life cycle on these lands	Appreciable numbers of big game found; antelope spend much of life cycle on these areas	A small population of big game animals exist for various periods on these lands

ards of use. The Soil Conservation Service is carrying out a commendable educational and action program, largely through contact with stockmen on their own holdings. Conducting a similar program on the scattered areas of the Forest Service and the Bureau of Land Management is complicated, but greater effort should be made.

In addition to extension and educational programs an effective research program is needed to improve relations between public land agencies and stockmen. Research can assure stability of tenure of qualified stockmen, and this is vital to encourage a better feeling between user and landlord.

Reorganization of Federal Land Agencies

Most scholars of Federal land administration agree that consolidation of control should be effected to the greatest practicable extent.

The Hoover Commission (*6, 7*), formed in 1947 to study and recommend reorganization of the executive branches of the Government, had two of its "task forces" primarily concerned with agricultural affairs and natural resources (*2*). The latter task force proposed a Department of Natural Resources, including the present Forest Service, to replace the Department of Interior. The agricultural activities task force recommended a reorganization of the Department of Agriculture to include a "Forest and Range Service" composed of the present Forest Service and Bureau of Land Management. Study of the prob-

lem by the departments concerned is under way It seems desirable to adopt some form of reorganization that will better coordinate the uses of public and private lands

Summary

The more important facts of this chapter are summarized in Table 38 comparing the three Federal land agencies that administer most of the public grazing lands State lands are not included, because their administration is too diverse

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